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OHIO MOSSES, BRYALES*

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The present paper is a continuation of the study of the mosses of Ohio. The method of procedure and nomenclature used is the same as in the report on the Polytrichales.

BRYALES.

Hermaphroditic or unisexual mosses with archegonia situated at the tip of the main stalks and of ordinary branches. Gametophores usually erect, varying widely in vegetative characters. Scales from broad ovate to setaceous. Sporangium with a definite columella; peristome double, developed from the ampithecium and derived from the cell walls of a single layer of cells; outer teeth thin, transversely barred, the plates of the outer sides of the segments mostly in two rows separated by a median zig-zag line; the inner teeth membranous, sometimes lacking; sporangium rarely without a peristome.

SYNOPSIS OF THE ORDER.

- I. Teeth of the endostome, when present, alternating with those of the exostome.
 - A. Sporangium regular, erect. ORTHOTRICHACEÆ
 - B. Sporangium elongated or pear-shaped, often with a neck-like hypophysis.
 - 1. Inner peristome with keeled segments, with inner cilia often present.
 - a. Sporangium only slightly or not at all zygomorphic, often pendent; hypophysis short or forming a long neck; inner peristome mostly with well-developed cilia. BRYACEÆ
 - b. Sporangium decidedly zygomorphic, arcuate, long-necked; inner peristome without intermediate cilia. MEESIACEÆ
 - 2. Inner peristome with basal membrane bearing cilia only, in twos or fours. TIMMIACEÆ
 - C. Sporangium more or less globose, without a neck-like hypophysis; inner peristome without cilia or with cilia little developed. BARTRAMIACEÆ
- II. Teeth of the endostome, when present, opposite those of the exostome, either free or united with those of the outer set.
 - A. Endostome processes, when present, free. FUNARIACEÆ
 - B. Endostome processes coherent with the exostome or absent.
 - 1. Minute cleistocarpous mosses. EPHEMERACEÆ
 - 2. Sporangium minute, without a peristome; scales 2-ranked, confluent below, without a mid-rib. SCHISTOSTEGACEÆ
 - 3. Sporangium with a very much enlarged hypophysis; scales more than 2-ranked. SPLACHNACEÆ

* Papers from the Department of Botany, The Ohio State University, No. 174.

KEY TO THE FAMILIES OF BRYALES.

1. Scales 2-ranked, vertically placed forming a continuous margin on the gametophore.....SCHISTOSTEGACEÆ
1. Scales 2 to 8-ranked, not vertically placed.....2
2. Plants dark except at the tip of the growing gametophores; on rocks and trees.....(ORTHOTRICHACEÆ) 3
2. Plants light green, or if blackish, then growing on the ground.....3
3. Plants minute, almost microscopic, one-eighth mm. or less; on soil sporangium immersed.....EPHEMERACEÆ
3. Plants larger, 8 mm. or more; on soil, rocks, or trees; sporangium on a seta.. 4
4. Cells on scales papillose.....5
4. Cells of scales not papillose.....7
5. Scales crisped when dry, strongly serrate.....TIMMIACEÆ
5. Scales not crisped when dry.....6
6. Scales obtuse, broadly ovate to oblong-ovate, serrate or entire. MEESIACEÆ
6. Scales acute to acuminate, serrate.....BARTRAMIACEÆ
7. Swollen or expanded hypophysis.....SPLACHNACEÆ
7. Hypophysis tapering.....8
8. Sporangium nearly actinomorphic, segments of inner peristome alternating with the teeth of the outer peristome.....BRYACEÆ
8. Sporangium strongly zygomorphic, segments of the inner peristome opposite the teeth.....PUNARIACEÆ

ORTHOTRICHACEÆ.

Gametophytes forming tufts of erect to ascending, dichotomously branched gametophores; scales solid, decurrent, oblong to linear-lanceolate, of mainly one layer of more or less uniform cells; seta erect, often short with the sporangium partly immersed; sporangium actinomorphic, erect, peristome double or single, rarely none, when double the segments alternating with the teeth.

1. Creeping with erect or ascending branches; calyptra cucullate, not plicate, *Drummondia*
1. Mostly erect; calyptra campanulate, plicate.....2
2. Scales ovate at the base, crisped when dry; sporangium exserted.....*Ulota*
2. Scales not ovate at the base, not crisped when dry; sporangium immersed or emergent.....*Orthotrichum*

1. DRUMMONDIA Hook.

Peristome of 16 teeth, distinct to the base, not distinctly twisted nor longitudinally striate; calyptra cucullate; on trees.

Drummondia prorepens Brid. (*Anodontium prorepens* Brid.; *Hypnum clavellatum* Dill.; *Gymnostomum prorepens* Hedw.; *Orthotrichum clavellatum* Hook.; *Drummondia clavellata* Hook.) Creeping, with many erect bulbous branches, radiculose below, dark green almost black, bright at the tips; scales broadly lanceolate, revolute, concave, erect to spreading, entire, costa strong; seta less than one-eighth inch long, reddish-brown, twisted when dry; sporangium short ovoid, almost globose, erect, mouth wide. Fruits in summer. Reported from Lake, Franklin, and Clark Counties.

2. ORTHOTRICHUM Hedw.

Scales not crisped when dry, bases not oval; stomata immersed in the neck of the sporangium; calyptra less densely hairy than *Ulota*; otherwise very like it.

1. On rocks; peristome single, teeth erect or erect-spreading when dry..... 2
1. On trees; peristome double, teeth more or less reflexed when dry..... 5
2. Sporangium fully exserted; 16-striate..... *O. anomalum*
2. Sporangium immersed or half-emergent; 8 or 16-striate..... 3
3. Half-emergent; 16-striate..... *O. cupulatum*
3. Sporangium immersed when growing; 8-striate..... 4
4. Sporangium half-emergent when dry; ovate-cylindrical..... *O. strangulatum*
4. Sporangium immersed when dry, ovate-globose..... *O. lescurii*
5. Sporangium strongly contracted below the mouth, deeply 16-striate, striæ reddish-brown..... *O. braunii*
5. Sporangium not strongly constricted below the mouth, less deeply striate, lighter in color..... *O. ohioensis*

Orthotrichum anomalum Hedw. (*O. saxatile* Brid.) Brownish, one-half to one inch tall; scales lanceolate, not crisped when dry, reflexed; sporangium lightly exserted, 16-striate, alternate striæ short and indistinct, hypophysis long and tapering, calyptra with few hairs, peristome teeth cross-barred, not reflexed when dry. On rocks. Autoicous. Early summer. Ottawa County.

Orthotrichum strangulatum Schw. (*O. porteri* Aust.; *O. cupulatum porteri* Venturi). Densely cespitose, one-third to one-half inch tall, branched; scales dense, ovate to lanceolate, acute, entire or papillose, somewhat revolute, costa strong, ending slightly below the apex; sporangium immersed when growing, may be only slightly so when dry, erect, ovate to cylindric, urn-shaped, 8-striate, reddish-brown, stomata immersed, few; calyptra densely erect-hirsute, operculum with rounded apiculation, peristome single, teeth often split. On rocks. Summer. No specimens in the herbarium but Jennings reports it as being found in Ohio.

Orthotrichum cupulatum Hoffm. (*O. strangulatum* Beauv.) Small dense tufts, about one-half inch deep; scales lanceolate, entire, revolute, costa ending below the point; seta short, sporangium half immersed, wide-ovate, 16-striate, with alternate striæ shorter than the others, constricted below the reddish-brown mouth, hypophysis short, calyptra sparingly hairy, covering the whole sporangium. Autoicous. Summer. Clark and Franklin.

Orthotrichum lescurii Aust. (*O. cupulatum minus* Sull.) Rather densely cespitose, about three-eighth inch tall, branched; scales dense, lanceolate to ovate, acute, entire, revolute, costa ending slightly below the apex; sporangium practically immersed, urn-shaped, ovate-globose, 8-striate, sometimes constricted below the mouth, operculum mamillate. On granite rocks. Spring. No specimen in the herbarium but it is probably found in Ohio.

Orthotrichum braunii Sch. (*O. strangulatum* Sull.) Cespitose, creeping with erect-spreading branches, less than one-fourth inch tall, dark green with lighter tips; scales entire, acute, revolute, clasping, not crisped when dry, costate; sporangium partly immersed, sharply 8-striate, reddish-brown, deeper color on the ribs, constricted below the mouth when dry, peristome double, teeth recurved, hypophysis short. Morgan Co.

Orthotrichum ohioënsis Sull. (*O. canadense* Sull.) Similar to *O. braunii* except in the nature of the sporangium which is lighter in color, not so deeply constricted below the mouth, nor so deeply 8-striate, neither are the peristome teeth reflexed; the plants are lighter green and taller with ovate-oblong scales; calyptra hairy. Autoicous with the antheridial clusters axillary. Specimen from Franklin County, reported from Lake and Lawrence.

Orthotrichum ohioënsis citrinum (Aust.) Lesq. and Jas. (*O. citrinum* Aust.) Scales lighter green, sporangium light yellow, thin, not constricted. Reported from Lake County.

3. ULÔTA Mohr.

Scales dark green to blackish, lighter at tips of the gametophores, spreading to squarose, concave, usually crisped when dry, costa percurrent or nearly so, strong. Sporangium erect, actinomorphic, striate when dry; stomata superficial on the hypophysis; calyptra mitrate, plicate, usually pubescent with erect hairs; peristome usually double, teeth with a median line on the longitudinal face.

1. On rocks; scales not crisped when dry..... *U. americana*
1. On trees; scales crisped when dry..... 2
2. Sporangium smooth, with striae near the mouth; mouth distinctly narrowed,
U. ludwigii
2. Sporangium distinctly striate; mouth wide..... 3
3. Sporangium constricted below the mouth, hypophysis long and tapering,
U. crispa
3. Sporangium not constricted below the mouth, hypophysis abrupt,
U. crispa minus

Uloata americana (Beauv.) Limp. (*Uloata hutchinsiae* Schimp.; *Orthotrichum hutchinsoniae* Sm.; *Weissia americana* (Pallis) Lindb.) "American Uloata." Loosely cespitose; scales lanceolate, not bordered, revolute, carinate, strongly nerved, closely appressed, not crisped when dry; seta about one-fourth inch long; sporangium yellowish, cylindric, hypophysis tapering, irregularly 8-striate, with more or less distinct intermediate ridges when dry. Autoicous. Spring. Lake County.

Uloata ludwigii (Brid.) Brid. (*Orthotrichum ludwigii* Brid.; *Weissia coarctata* Lindb.) "Puckered Uloata." Loosely cespitose, creeping with erect branches, one-fourth to three-eighth inches tall, densely tomentose below; scales narrowly lanceolate, long, acute to acuminate, somewhat twisted when dry, dense, entire, revolute, concave at the base, erect-spreading, costa sub-percurrent; seta short, yellowish, twisted when dry; sporangium erect, short-pyriform, striae short below the mouth, hypophysis long and tapering, peristome usually single. Autoicous. On trees in woods. Summer. No specimen.

Uloata crispa (L.) Brid. (*U. ulophylla* Broth.; *Orthotrichum crispum* Hedw.; *Bryum crispum* Gmel.; *Weissia ulophylla* Ehrh.) "Crisped Uloata." Densely cespitose, about one-half inch tall, gametophores erect and sparingly branched; scales dense, narrowly lanceolate, curled when dry, erect when moist, entire, acuminate, costa percurrent; seta short, sporangium scarcely emergent, erect, 8-striate, slightly constricted below the mouth, teeth reflexed when dry, hypophysis tapering. Autoicous. On trees. Summer. Not reported from Ohio but Jennings reports it as abundant in western Pennsylvania.

Ulotia crispa minus Sche. (*U. crispa crispula* Hamm.; *U. crispula* Bruch.; *Weissia ulophylla crispula* (Bruch.) Hamm.) Similar to *U. crispa* in appearance, but with both the gametophores and the scales shortened; seta one-fourth to three-eighth inches long, sporangium erect, sub-globose, not constricted below the mouth, striæ indistinct, hypophysis shorter than in *U. crispa*. Late spring and early summer. No specimen but is reported from Lake County.

BRYACEÆ.

Gametophytes small; upper scales usually larger than the lower ones, not winged nor clasping, often bordered by long narrow cells, costa excurrent, upper scale surface smooth; seta long, sporangium more or less zygomorphic, bent, drooping, or pendulous; pear-shaped, ovoid to cylindrical; calyptra smooth, early deciduous; peristome double, outer teeth 16, segments of the inner peristome alternating with the teeth, segments and teeth about equal in length, inner with a distinct carinate membrane, teeth with a median longitudinal line on the outer face; sporangium smooth when dry; protonema not persistent.

1. Rhizome-like stalk, with erect branches with a conspicuous comal tuft of larger scales..... *Rhodobryum*
1. Not rhizome-like, but may be inclined or arched, radiculose below; not conspicuously tufted..... 2
2. Fertile gametophores with more or less tufted scales, sterile shoots longer, arched, often producing rhizoids..... *Mnium*
2. Gametophores all similar, erect-ascending, radiculose below..... 3
3. Scales ovate to ovate-lanceolate..... 5
3. Scales linear-lanceolate to linear..... 4
4. Scales linear from a broader base, setaceous..... *Leptobryum*
4. Scales linear-lanceolate..... *Webera*
5. Scales not bordered; stomata immersed..... *Mniobryum*
5. Scales bordered; stomata superficial..... *Bryum*

1. LEPTOBRYUM (Schimp.) Wils.

Cells of scales narrow, linear-rhomboidal; cilia not distinctly appendiculate, scales not bordered, not papillose; sporangium pendulous, pyriform, smooth or only slightly and irregularly wrinkled; costa long-excurrent. Annual.

Leptobryum pyriforme (L.) Wils. (*Webera pyriformis* Hedw.; *Byrum pyriformis* Hedw.; *Mnium pyriforme* L.) "Long-necked Bryum." Densely cespitose, soft, one-half to one inch tall, yellowish-green, brown and matted below; scales elongated, linear-setaceous, erect-spreading, in dense terminal tufts, margins denticulate above, costa excurrent; seta very slender, one-half to one inch long, light-brown; sporangium pendulous, pyriform, reddish-brown, shiny, hypophysis narrow, tapering, darker than the oval-globose sporangium, operculum hemispherical. Synoicous. Wet shaded rocks and soil. June and July. Reported from Lake and Clark, and is common in green-houses in Franklin County.

2. WEBERA Hedw. (*Pohlia* Hedw.)

Scales linear-lanceolate above, broadly ovate to obovate below, green to yellowish-green, often glossy, scale-cells linear to rhomboidal,

more than twice as long as broad, costa ending some distance below the apex, margin entire or more or less toothed near the apex only; costa narrow, scales inserted in 2 or 3 rows.

1. Stalks and costa reddish, densely cespitose..... 2
1. Stalks not reddish, costa reddish near the base..... *W. lescuriana*
2. Moist soil in rocky places and clefts of rocks; upper scales long shining, red at the base..... *W. cruda*
2. Wet peaty soil and decaying wood; scales shorter, red only on the costa, *W. nutans*

Webera cruda (L.) Schw. (*Pohlia cruda* Lindb.; *Bryum crudum* Schreb.; *Mnium crudum* L.) Densely cespitose, one to three inch tall stalks reddish, simple; scales erect-spreading, slightly serrate near the apex, glaucous green and shining; sporangium horizontal, cylindrical or only slightly constricted below the mouth, hypophysis indistinct, short, light brown, teeth yellow, seta long. In moist soil and rocky places or in clefts in the rocks. Usually autoicous. Summer. Reported from Lake County by Jennings.

Webera nutans (Schreb.) Hedw. (*Pohlia nutans* Lindb.; *Bryum nutans* Schreb.) Densely cespitose, branching, one-half to 2 inches tall, green above, dense brown tomentum below; lower scales ovate, upper ones linear-lanceolate in dense terminal tufts, denticulate near the apex, stalks and costa near the base reddish; seta glossy, reddish-brown, one-half to 2 inches long; sporangium horizontal to sub-pendulous, ovoid, light brown, mouth wide, constricted below the mouth, operculum mamillate, convex, hypophysis long tapering. Autoicous. Early summer. Wet soil and wet decaying wood. Common.

Webera lescuriana (Sull.) Jacq. (*Bryum pulchellum* Sull.; *Bryum lescuriana* Sull.) Loosely cespitose, pale, stems not red, simple, ascending; scales small and remote below, larger and more dense above, lanceolate, acuminate, serrulate, recurved, not decurrent, reddish; seta erect, one-third to one-half inch long, yellowish-brown, lustrous; sporangium horizontal to pendulous, yellowish-brown, pyriform, hypophysis short, darker, mouth wide, operculum conic-apiculate to mamillate, peristome teeth yellowish pellucid. On wet soil. Unisexual. May. Fairfield and Lake.

3. MNIQBRYUM (Schimp.) Limp.

Small plants with the upper scales linear-lanceolate, glaucous-green, cells of the scales more or less rhombic-hexagonal, more than twice as long as broad, never linear except in the margin; cilia not distinctly appendiculate; distinctly serrulate.

Mniobryum wahlenbergii (Web. & Mohr.) Jen. (*M. albicans* Limp.; *Bryum wahlenbergii* Schw; *Hypnum wahlenbergii* Web. & Mohr.; *Webera albicans* Schimp.) Loosely cespitose, large up to three inch tall, stalks slender, flexuous, reddish; scales distant, linear-lanceolate, slender and long-pointed; seta erect, slender, flexuous, sharply hooked at the summit; sporangium pendent, reddish-brown, pyriform; wide mouth, no annulus, hypophysis short and wide, stomata immersed. Unisexual. Spring and summer, fruiting rarely. Wet soil of banks and ditches. Athens, Hocking, Butler, Lawrence, Clark, Champaign.

4. BRYUM (Dill.) Schimp.

Smaller mosses, usually densely tufted, non-stoloniferous, densely woven radicles, branching; scales often bordered, costa usually excurrent; sporophytes single, seta long, sporangium usually pendulous, peristome of 16 long lanceolate teeth and 16 segments alternating with the teeth, inner peristome with a basal membrane cilia appendiculate.

1. Branches julaceous, silvery.....*B. argenteum*
1. Branches not julaceous; reddish or green, not silvery..... 2
2. Inner peristome imperfect, membrane often united with the teeth..... 3
2. Inner peristome perfect..... 5
3. Teeth marked longitudinally.....*B. cernuum*
3. Teeth not marked longitudinally..... 4
4. Sporangium actinomorphic or only slightly curved; mouth oblique, small; on wet soil.....*B. uliginosum*
4. Sporangium incurved, zygomorphic; mouth not oblique; dry heaths and walls.....*B. inclinatum*
5. Costa vanishing below the apex.....*B. capillare*
5. Costa percurrent to long-excurrent..... 6
6. Scales long-decurrent; costa short-excurrent..... 7
6. Scales short-decurrent or non-decurrent; costa long-excurrent..... 8
7. Gametophores unisexual.....*B. pseudotriquetrum*
7. Gametophores synoicous.....*B. bimum*
8. Scales short-decurrent.....*B. affine*
8. Scales non-decurrent..... 9
9. Scales distinctly bordered, borders yellowish.....*B. pallescens*
9. Cells at edge of scale narrowed but scarcely forming a border.....10
10. Gametophytes unisexual; operculum deciduous.....*B. caespiticum*
10. Gametophytes synoicous; operculum more persistent.....*B. intermedium*

Bryum cernuum Hornsch. (*B. pendulum* Schimp.; *Cynodontium cernuum* Hedw.) Stalks red, erect; scales ovate-lanceolate, tufted, acuminate, reddish at the base, twisted when dry, costa conspicuous, red near the base, excurrent; seta light brown, copperish, one to one and one-fourth inch long, sporangium pendulous, cylindrical, mouth wide, teeth long acuminate, yellowish below, clear near the tips, inner peristome adherent, segments often split, cilia rudimentary. Synoicous. Spring and early summer. Clark County. Lesquereux lists it from "Southern Ohio."

Bryum inclinatum (Sw.) Bland. (*Pohlia inclinata* Sw.) Deep green, tufted; scales clasping, acuminate, ovate-lanceolate, denticulate near the apex, red at the base, revolute, long hyaline, with yellowish borders; seta one to one and one-half inch long, sporangium pyriform or slightly curved, narrow at the mouth, brown, cilia none or rudimentary, hypophysis tapering. Summer. On walls and slaty rocks. Summit County.

Bryum uliginosum Br. and Sch. (*B. cernum* Lindb.; *Cladodium uliginosum* Brid.) Gametophyte similar to *B. inclinatum*; seta one and one-half to two inches long, reddish-brown, lustrous; sporangium horizontal to sub-pendulous, large, often one-quarter inch long, incurved, teeth pale yellow, cilia absent or rudimentary, hypophysis tapering. Autoicous. Late summer. No specimen.

Bryum bimum (Schreb.) Brid. (*Mnium bimum* Brid.) Loosely cespitose, lax, matted together, stalks red, branches sparse; scales long,

slender, lanceolate, decurrent, appressed, revolute, pale, serrulate, in outer portion, slightly twisted when dry, distinctly bordered, costa short-excurrent, purplish-red; seta one to two and one-half inches long, slender, castaneous; sporoangium pendulous, reddish-brown, slightly or not at all constricted below the mouth, frequently upcurved, annulus large, teeth slightly sub-hyaline, segments shorter than the teeth, cilia appendiculate, hypophysis tapering. Syniocous. On wet soil and decaying wood. Summer. Stark, Clark, Lorain, Summit, Hancock, Champaign.

Bryum pseudotriquetrum (Hedw.) Schw. (*B. ventricosum* Dick.; *Mnium pseudotriquetrum* Hedw.) Similar to *B. bimum* but is unisexual, and generally larger and stouter. Tip of antheridial branch large and discoid. Spring and early summer. Vinton, Clark, Fairfield, Champaign.

Bryum affine (Brid.) Lindb. (*B. cuspidatum* Schimp.; *Webera affinis* Bruch.) Gametophores one-quarter to two inches or more in height; scales densely tufted, slightly decurrent, acuminate, more or less serrulate near the apex, almost entire, revolute, slightly twisted when dry, ovate-lanceolate, reddish near the base, costa excurrent, reddish; seta one to one and one-half inches long, lustrous, castaneous; sporangium horizontal to pendulous, oblong-pyriform, constricted below the mouth when dry, hypophysis tapering, yellowish-brown, operculum convex, mamillate, peristome yellowish-pellucid below, sub-hyaline above, segments shorter than the teeth, cilia appendiculate. Syniocous. Summer. Damp walls and rocks. Not reported from Ohio, but is found in western Pennsylvania near our border.

Bryum intermedium (Ludw.) Brid. (*Mnium intermedium* Ludw.; *Webera intermedia* Schw.) Dark, bronze green, one-half to one inch tall, stalks reddish, scales tufted, long-acuminate, revolute, almost entire, concave, recurved, slightly decurrent, costa excurrent in a long awn; seta three-quarters to one inch long, copper colored and glistening; sporangium horizontal to almost pendulous, elliptic-pyriform, often in-curved, brown, redder near the mouth, teeth lighter, incurved when dry, hypophysis long tapering and often curved. Syniocous. July and August. Cliffs, walls and wet sand. Clark County.

Bryum pallescens (Schl.) Schw. (*B. turbinatum* Drum.) Yellowish-green, one-half to two inches deep; scales tufted, sparse below, ovate to ovate-lanceolate, acuminate, erect-spreading, reddish at the base, recurved slightly, twisted when dry, costa excurrent in a long point, toothed, reddish; seta about one inch long, erect, flexuous, lustrous, castaneous, sporangium inclined to sub-pendulous, oblong-pyriform, hypophysis tapering, cilia appendiculate, in threes, yellowish. Autoicous with antheridia on a separate branch. May or June. Rocks and crevices in walls. No specimen, but it is reported from Lake County.

Bryum caespitium (L.) Hedw. Gametophores one-half to one inch tall, very slender, light bright green; scales ovate to lanceolate, acuminate, entire, revolute, concave, dense near tip of the gametophore, small and distant below, costa long-excurrent, reddish; seta copper-colored, two-thirds to one-half inch long, flexuous; sporangium horizontal to pendulous, slightly or not at all constricted below the

mouth, cilia appendiculate, segments as long as the teeth, hypophysis tapering. Dioicous. Early summer. Delaware, Fairfield, Clark, Hardin.

Bryum argenteum (L.) Hedw. "Silvery Bryum." Gametophores small and compact, one-quarter to one inch or less; scales broad ending in a bristle, clasping, concave, compressed, light green, silvery when dry, entire, very pellucid, costa ending below the apex; seta one-third to one-half inch long, sharply curved at the top, sporangium pendulous, reddish-brown, slightly constricted below the mouth, cilia as long as the segments, operculum yellowish. Autumn. On dry earth, crevices in walks, etc. Lake, Franklin, Clark.

Bryum capillare (L.) Hedw. (*Mnium capillare* L.) Gametophores small, one-half inch or more in height; scales dense near the top of the gametophore; light green, lanceolate, revolute, entire, costa brown, excurrent; seta one-half to three-quarters inches long, slender, brown; sporangium horizontal to sub-pendulous, brown, slightly constricted below the mouth, peristome conspicuous, hypophysis long and tapering. Usually unisexual. Summer; fruit rarely found. Loam and leaf mold. Greene County.

5. RHODOBRYUM (Schimp.) Hampe.

Large stoloniferous mosses with clustered sporophytes.

Rhodobryum ontariense (Kind.) Paris. (*Bryum roseum* L. & J.; *Bryum ontariense* Kind.; *Bryum proliferum* (L.) Shibth.; *Mnium roseum* Weis.) "Giant Bryum." Large, yellowish-green, with sudden conspicuous terminal tufts of scales, long and creeping, branches one to two inches tall; scales large, almost one-half inch long, acute, sharply serrate, wavy when dry, costa percurrent; seta one and one-half to two inches long, brown; sporangium paler, slightly curved, horizontal, teeth bordered, hypophysis long and tapering. Unisexual. On rotting wood and humus. Specimens from Champaign, Fairfield and Clark and reported from Franklin by Professor Schaffner.

6. MNIMUM (L.) Hedw. (*Astrophyllum* Neck.)

Large plants, upper scales ovate, cells of the scales rhomboidal-hexagonal, nearly as broad as long, never linear; sporangium cylindrical-oblong to ovoid, pendulous; cilia not appendiculate.

- | | |
|--|----------------------|
| 1. Scales not bordered..... | <i>M. stellare</i> |
| 1. Scales bordered..... | 2 |
| 2. Scales entire or nearly so..... | <i>M. punctatum</i> |
| 2. Scales distinctly serrate..... | 3 |
| 3. Scales serrate with a single row of teeth..... | 4 |
| 3. Scales serrate with a double row of teeth..... | 5 |
| 4. Scales serrate to the base or nearly so; sporophytes clustered..... | 7 |
| 4. Scales serrate in outer two-thirds or one-half only..... | 6 |
| 5. Scales usually acute; lid conic; unisexual..... | <i>M. affine</i> |
| 5. Scales usually obtuse; lid rostrate; synoicous..... | <i>M. rostratum</i> |
| 6. Scales not much crisped when dry; sporophytes clustered.... | <i>M. drummondii</i> |
| 6. Scales much crisped when dry; sporophytes single..... | <i>M. cuspidatum</i> |
| 7. Scales lanceolate; costa not reaching the apex; dorsally toothed.. | <i>M. hornum</i> |
| 7. Scales lance-ovate; costa percurrent in the upper scales; not dorsally toothed..... | 8 |
| 8. Peristome red; cells of the scales collenchymatous..... | <i>M. spinulosum</i> |
| 8. Peristome yellow; cells of the scales not collenchymatous..... | <i>M. serratum</i> |

Mnium hórnum (L.) Hedw. (*Astrophyllum hornum* Lindb.) "Long-scaled Mnium." Cespitose, dark to bright green, one to two inches tall, unbranched, scales long-acuminate, curled when dry, costa distinct, ending below the apex, scales on the sterile shoots crowded, antheridial branch tip discoid; seta one-half to three-quarters inches long, reddish-brown, slender; sporangium yellow with a red mouth, sub-pendulous, ovate-elliptical, calyptra often clinging to the seta. Unisexual. On cliffs near streams or on sandy banks. Franklin County.

Mnium serrátum (Schrad.) Schw. (*M. marginatum* Beauv.; *Astrophyllum marginatum* Lindb.; *Bryum serratum* Schrad.) Loosely cespitose, one-half to one inch tall, dark, stalks reddish, densely tomentous below; scales distant, ovate to obovate, acute, costa reddish, percurrent in the upper scales, shorter below, serrate margins reddish, strongly decurrent; seta one-half to three-quarters inches long, pale, sporangium horizontal, ovoid, light yellow, hypophysis tapering, operculum rostrate. Synoicous. Early spring. Moist shaded banks or in crevices of rocks. Reported from Ohio by Lesquereux, but no specimens are in the herbarium.

Mnium spinulòsum Br. & Sch. "Red-mouthed Mnium." Less than one inch tall; scales obovate to spatulate, acute, decurrent, reddish bordered, costa usually percurrent, sporophytes single or clustered; erect; sporangium inclined to horizontal, ovate-oblong, light yellowish, annulus bright red, peristome red, operculum decidedly rastrate. On ground in evergreen woods. Reported from Lake County.

Mnium rostrátum (Schrad.) Schw. (*Astrophyllum rostratum* Lindb.; *Bryum rostratum* Schw.) Large, loosely cespitose, stoloniferous, branches erect, short; scales oblong to obovate, obtuse, costa shortly excurrent; sporophytes 1-3, sporangium horizontal to sub-pendulous, yellowish, peristome yellow, inner peristome orange, operculum rostrate. Synoicous. Spring. Earth or rocks in moist shady places, wet by spray. Specimen from Fairfield. Reported from Champaign.

Mnium cuspidátum (L.) Hedw. (*M. sylvaticum* Lindb.; *Astrophyllum sylvaticum* Lindb.) "Woodsy Mnium." Cespitose, prostrate to suberect, about one inch tall, light green, brown radicle below; scales distant, oblong-ovate or somewhat ovate, acute, decurrent, keeled, wavy when dry, serrate in the upper half, teeth usually of one cell, costa strong, vanishing below the apex; seta about one inch long, solitary, light brown, glistening; sporangium horizontal to sub-pendulous, light brown, peristome light, cilia as long as the teeth, hypophysis very short, deeper brown, calyptra pointed, splitting on the side. Synoicous. May. Cosmopolitan on rotten wood, stones and soil. Common.

Mnium drummondii Br. & Sch. Gametophytes one to one and one-half inches tall, loosely cespitose, with dense brown tomentum below; scales distant, large, one-eighth inches long, broadly ovate, mucronate, costa excurrent; seta one and one-half to two inches long, slender, flexuous, copper-colored, sharply curved; sporangium pendulous, light brown, ovoid, reddish at the mouth, segments of the inner peris-

tome as long as the teeth, hypophysis short. May-June. No specimen in the herbarium, but it is reported from Lake County by Claassen.

Mnium affine (Bland. Schw.) (*M. cuspidatum* Neck.; *Astrophyllum cuspidatum* Lindb.) Gametophytes large, one to three inches tall, pale green, darker when older, brown radiculose below; scales widely distant, ovate, acute, narrow at the base, decurrent, serrate to the base, border pellucid or often yellowish or reddish, teeth single; costa distinct, excurrent; tip of antheridial branch discoid, large; sporophytes usually clustered, seta reddish; sporangium pale yellow, pendent, ovoid-elliptical, cilia as long or longer than the teeth, hypophysis short. Unisexual. May. Rocks and wet soil. No specimen.

Mnium affine ciliare (Gren.) Muell. (*Astrophyllum ciliare* Lindb.) *Bryum ciliare* Grev.) "Toothed *Mnium*." Similar to *M. affine* with the exception that the sporophytes are single and never clustered, and the teeth on the scales are longer than in *M. affine*. Franklin, Champaign, Hardin.

Mnium affine rugicum Br. & Sch. (*Astrophyllum rugicum* Lindb.) Smaller, blackish with lighter green tips; scales oblong to orbicular, teeth almost obsolete, almost entire, very short; apex rounded; sporophytes single. Cool shaded ravines and swamps. Spring. Not reported but may be found.

Mnium stellare (Reich.) Hedw. (*Astrophyllum stellare* Lindb.) Densely cespitose, one-third to two inches tall, deep or bluish-green, soft, erect, branching at the base; scales slightly decurrent, apex rounded to obtuse-apiculate, dense, oblong-elliptic, slightly crisped when dry, non-bordered, teeth obtuse, rather distant in the outer half, costa ending well below the apex; tip of antheridial branch discoid; sporophyte solitary, sporangium inclined to horizontal, oblong, operculum conic-convex, peristome yellowish. Unisexual. Summer. Rarely found in fruit. Bases of trees in swampy woods. There is no specimen in the herbarium, although Beardslee reports this species as common and Miss Biddlecomb reports it from Clark County.

Mnium punctatum (L.) Hedw. (*Astrophyllum punctatum* (L.) Lindb.) "Early *Mnium*." Large, one to three inches tall, loosely cespitose, dark green, radiculose almost to the top; scales broad ovate, blunt, narrow at the base, scarcely decurrent, margin thick, costa strong, large up to one-quarter inch long; seta to one inch long, brown, sporangium sub-pendulous, light, becoming darker, operculum acutely rostrate, peristome yellowish, papillose. Unisexual. Early spring. This species is reported common by Beardslee, but there is no specimen in the herbarium.

MEESIACEÆ.

Gametophytes small to medium size; scales 3-8-ranked, with laminae of one layer of more or less uniform cells, not clasping, lanceolate to lance-ovate, recurved to spreading, squarose, obtuse or rounded, costa strong; seta usually very long and slender; sporangium arcuate with long tapering hypophysis, not constricted below the mouth; outer peristome of 16 teeth with a median line on the outer face, inner peris-

tome of 16 segments alternate with the teeth, keeled, cilia rudimentary, with a carinate basal membrane; calyptra cucullate. In bogs frequently with sphagnum.

1. Peristomes of equal length; surface cells of the scales papillose; sporangium striate when dry.....*Aulacomnium*
1. Inner peristome longer than the outer; surface cells of the scales not papillose; sporangium smooth or irregularly sulcate when dry.....*Meesia*

1. AULACÓMNIUM Schw.

Scales strongly costate, cells collenchymatous; sporangium ovoid-cylindrical, somewhat zygomorphic, ribbed when dry, outer and inner peristome of equal length.

1. Scales ovate, strongly serrate; autoicous.....*A. heterostichum*
1. Scales lanceolate, serrate near the apex only; unisexual.....*A. palustre*

Aulacomnium heterostichum (Hedw.) Br. & Sch. (*Sphaerocephalus heterostichus* (Brid.) Britt.; *Arrhenopterum heterostichum* Hedw.; *Orthopyxis heterosticha* Beauv.) Loosely caespitose, much branched, yellowish-green, one to one and one-half inches tall, more or less prostrate, radiculosous below; scales ovate, lower ones obovate, rounded at the tip, costa yellowish-brown extending to just below the apex; seta reddish-brown, one-tenth to one-third inches long, sporangium reddish, curved, inclined, oblong-cylindric, 8-striate, hypophysis tapering, peristome light yellow, cilia slightly shorter than the teeth, operculum with a short blunt point. May and June. on rocks and sandy soil in the shade. Common throughout the state.

Aulacomnium palustre (L.) Schw. (*Mnium palustre* L.; *Sphaerocephalus palustris* (L.) Lindb.) "Ribbed Bog-Moss." Caespitose, branching, one to five inches tall yellowish-green with brown tomentum below, scales linear-lanceolate, to wider, acuminate, costa to just below the apex, serrate near the tip, crispate when dry, cells papillose; seta three-quarters to two inches long, yellowish-brown, twisted; sporangium arcuate, constricted below the mouth, reddish-brown, 8-striate, hypophysis long-tapering, a distinct line separating it from the body of the sporangium, peristome yellowish, operculum conic with a short blunt tip. Antheridial tip discoid. Reported from Lake County by W. C. Werner.

Aulacomnium palustre polycephalus Br. & Sch., which is reported from Champaign County by Werner, is described by Dixon as "a gemmiferous form" which produces pseudopodia from the axils of the scales and he thinks it a state rather than a true variety.

2. MÊESIA Hedw.

Sporangium smooth, not ribbed when dry, segments two or three times as long as the teeth; costa thick.

1. Scale margins revolute, apex rounded.....*M. trichoides*
1. Scale margins plane, apex acute..... 2
2. Scales entire, 5 to 8-ranked.....*M. longiseta*
2. Scales serrate, 3-ranked.....*M. triquetra*

Meesia trichoides Spruce. (*Bryum trichoides* L.; *Meesia uliginosa* Hedw.) Dense pale green tufts; scales long and narrow, in 8 rows. Synoicous. No specimen.

Meesia triquetra (L.) Angstr. (*M. tristicha* Br. & Sch.) Loosely cespitose, dark green, radiculose below, sparingly branched; scales lanceolate, acute, decurrent and half-clasping, distant, keeled, squarose; sporangium pyriform, curved from a long erect collum, more or less twisted and wrinkled when dry, segments of the inner peristome about three times as long as the teeth, yellowish, operculum convex. In peat bogs. Reported from Southern Ohio, in H. C. Beardslee's catalog.

Meesia longisetia Hedw. Scales entire, decurrent, lanceolate, gradually spreading from an erect base, not squarose, crisped when dry. Synoicous. "Cranberry swamps in northern Ohio, not rare" according to Lesquereux and James.

BARTRAMIACEÆ.

Large deep tufts or cushions of branched gametophores, protonema persistent; scales papillose, not winged or clasping, laminae of mainly one layer of more or less uniform cells; sporangium sub-globose, ribbed when dry, drooping, inner peristome shorter than the outer with a distinct carinate basal membrane, outer peristome of 16 teeth with a median line on the outer face.

1. Cilia rudimentary or lacking; scales linear-lanceolate.....*Bartramia*
1. Cilia well-developed, except in *P. muhlenbergii*; scales ovate-lanceolate,
Philonotis

1. BARTRAMIA Hedw.

Scales little or not at all decurrent, cells papillose; sporangium striate, somewhat globose.

Bartramia pomiformis (L.) Hedw. (*Bryum pomiforme* L.) "Apple Moss." Cespitose, matted, soft, one-fourth to two inches tall, yellowish-green, dense, brown tomentum below; scales elongated, somewhat decurrent, spreading, concave at the base, margins revolute in the lower part, serrate near the tip, crowded, costa excurrent, distinct; seta reddish-brown, one-quarter to one-half inches long, sporangium light-brown, globose, 16-striate, zygomorphic, peristome reddish, segments shorter than the teeth, operculum short-umbonate. Cosmopolitan mosses found on rocks and moist soil in the shade. May and June. Common.

2. PHILONOTIS Brid.

Water-loving mosses with well-developed cilia; usually unisexual.

1. Scales not dimorphic, cilia rudimentary.....*P. muhlenbergii*
1. Scales dimorphic, cilia well-developed..... 2
2. Perigonial bracts obtuse, triangular, ovate, costa not reaching the apex,
P. fontana
2. Perigonial bracts long-acuminate with excurrent costa.....*P. calcarea*

Philonotis muhlenbergii (Schw.) Brid. (*P. marchia* Sull.; *Bartramia muhlenbergii* Schw.) Cespitose, yellowish-green, brown below, gametophores slender, stalks reddish, one-half to one and one-half inches tall, branches whorled; scales lanceolate to ovate, long-acuminate, distant, decurrent, falcate-secund, ascending or appressed, somewhat crisped when dry, serrate in the outer portion, costa percurrent; seta copper-

colored, glistening, slender, flexuous; sporangium globose, zygomorphic, faintly striate, arcuate, cernuus, neck sunken when dry, brown, teeth reddish, operculum almost flat, umbo short. June. Wet rocks. Lake and Clark.

Philonotis calcarea Schimp. (*Bartramia calcarea* Br. & Sch.) Densely cespitose, soft, bright green, somewhat glaucous above, branches in whorles, slender, erect, three to four inches tall; reddish-brown dense tomentum below; scales broadly ovate on the main stem, acuminate, concave, plicate, serrulate toward the apex, margin revolute, base slightly decurrent, erect-spreading to secund, costa strong, dorsally papillose; branch scales lanceolate, falcate-secund; sporangium similar to *P. fontana*. Summer; rarely in fruit. Calcareous bogs and swamps. Not reported but may be found.

Philonotis fontana (L.) Brid. (*Mnium fontanum* L.; *Bartramia fontana* Swartz.) Gametophyte tall, one to five inch stalks very slender, red, brown tomentum below; scales small, appressed, usually turned to one side when dry, ovate-lanceolate, acuminate, yellowish-green, costa often excurrent into a short point; seta red. One-half to one and one-half inches long; sporangium brownish, oblong, arcuate, striate, teeth reddish-brown; tips of antheridial branches red and discoid. Dripping rocks and swampy places. Lake, Licking, Fairfield.

TIMMIACEÆ.

Robust mosses, dull yellowish-green with brown tomentum below, scales spreading to recurved, base half-sheathing, non-decurrent, non-bordered, serrate, costa percurrent; sporangium cernuus to almost pendent, peristome double.

1. TIMMIA Hedw.

Protonema not persistent; upper scale surface papillose; sporangium smooth not ribbed when dry; inner peristome with a distinct basal membrane, cilia as long as the teeth.

Timmia cucullata Rich. (*T. megapolitana* Hedw.) Large moss resembling *Polytrichum*; scales narrow, long, coarsely serrate, in six series, spreading to recurved; seta straight at end of stalk; sporangium curved, ovoid to cylindrical, regularly furrowed when dry, hypophysis tapering, peristome double, teeth equidistant, inner peristome of cilia only in groups of fours, zygomorphic, strongly curved when dry, tapering gradually to the seta, calyptra remaining on the seta. May. Moist soil and bases of trees. Clark County.

FUNARIACEÆ.

Protomena sometimes persistent; upper scales concave forming a rosette, costa distinct, rarely excurrent; seta red and twisted, segments of the inner peristome opposite the teeth, keeled, no basal membrane, no cilia; mostly on moist earth or earth-covered rocks.

1. Protonema not persistent; scales without costa. 2
1. Protonema persistent; scales without costa; calyptra splitting and remaining on the seta. *Discelium*
2. Sporangium curved or mouth tilted to one side, peristome usually double; seta elongated. *Funaria*
2. Sporangium actinomorphic, peristome none. 3
3. Sporangium splitting equatorially, immersed and almost sessile, *Aphanorhegma*
3. Sporangium definitely operculate, with a long seta or immersed, *Physcomitrium*

1. APHANORHÉGMA Sull.

Earth mosses, light green, radiculose at the base, glabrous; cells elongated above the middle of the scales.

Aphanorhegma serratum (Hook & Wils.) Sull. (*Physcomitrium serratum* Muell.) Gregarious, erect, simple or forked, small; lower scales spreading, oblong-lanceolate, upper ones more erect, larger, spatulate-lanceolate, sparingly serrate above the middle, apex acute to acuminate, costa almost to the tip; seta short and stout; sporangium immersed, brown, annulus near the middle, calyptra mitreform; spores orange. Autumn. Wet clay soil. Reported from Ohio by Lesquereux.

2. PHYSCOMÍTRIUM (Brid.) Fuer.

Earth mosses, light green; cells elongated above the middle of the scales; sporangium exserted on a long seta, or if immersed then with 1-3 rows of denser cells below the line of dehiscence; sporangium operculate, erect, no peristome, calyptra mitrate.

1. Sporangium immersed, mouth wide, calyptra small. *P. immersum*
1. Sporangium exserted, mouth narrow, calyptra larger. *P. turbinatum*

Physcomitrium immersum Sull. (*Gymnostomum immersum* Sull.) Gregarious, one-eighth to one-quarter inch tall, antheridia in axils of the scales, branches bearing the archegonia coming from below; scales obovate to lanceolate, costa ending below the apex, serrate above the middle; sporangium immersed, globose, brown, erect, operculum apiculate, rostrate. Autumn. Clay banks where they are sometimes submerged. Reported from Lake County and from "river banks of southern Ohio" by Lesquereux and James.

Physcomitrium turbinatum (Rich.) Muell. (*P. pyriforme* E. G. Britt.; *Phascum strangulatum* Kind.; *Phascum hookeri* Macoun.) "Urn Moss." Gregarious, small, one-half inch or less, erect; scales slightly serrulate, oblong or oblanceolate, curled when dry; seta pale, slender to one-half inch long, sporangium erect, actinomorphic, globose to pyriform, turbinate and constricted below the mouth when empty, operculum flatly convex, rostrate, blunt, short. Autoicous. Late spring or early summer. On bare soil under trees and by roadsides, also on earth in greenhouses. Specimens from Franklin, Trumbull, Clark, Lawrence and Hamilton; reported from Lake.

2. FUNÀRIA (Schreb.) Hedw.

Protonema not persistent, scales not clasping or winged; sporangium operculate, wrinkled when dry; calyptra cucullate; inner peristome

usually distinct, lacking a basal membrane or cilia, outer peristome of 16 teeth with a median longitudinal line on the outer face. Autoicous.

1. Scales short-acuminate, costa mostly percurrent. *F. hygrometrica*
1. Scales long-acuminate, costa excurrent in some of the scales. 2
2. Sporangium striate and more or less plicate, annulus large. *F. flavicans*
2. Sporangium neither striate nor plicate, no annulus. *F. americana*

Funaria americana Lindb. (*F. muhlenbergii* Hedw.) Small, gregarious, loosely caespitose; scales erect-spreading, long-acuminate, oblong-ovate, entire, not revolute, costa excurrent; seta twisted when dry, sporangium erect, mouth to one side, curved when dry, smooth, hypophysis long and tapering, rugose when dry. May. On soil. No specimens. Reported from Ohio by both Jennings and Grout.

Funaria flavicans (Rich.) Michx. Atheridial gametophores erect; lower scales small, sparse, and ascending; upper ones tufted and spreading, lanceolate, long-acuminate, entire, costa excurrent; archegonial gametophores shorter, scales ovate, acute; seta reddish-yellow, glistening, one to one and one-half inches long; sporangium arcuate, reddish-brown, striate, hypophysis tapering, operculum almost flat, not apiculate, calyptra long-pointed. May or June. Moist clay soil. Specimens from Lucas and Lawrence.

Funaria hygrometrica (L.) Sibth. (*Mnium hygrometricum* L.) "Cord Moss." Gametophyte one-eighth to one-third inches erect, radiculose; scales wide ovate, acute, concave forming a bulbous tuft, light green, entire or nearly so, costa dark red, percurrent; seta copper-colored to dark red, slender, flexuous, twisted when dry, one to two inches long; sporangium strongly arcuate, mouth to one side; reddish, yellowish, or brown; striate, hypophysis tapering, operculum almost flat, not apiculate, annulus conspicuous, calyptra long-rostrate, peristome teeth united by their tips to a small disk. Autoicous. May or June. Common on soil especially on burnt-over ground. Throughout the state.

Funaria hygrometrica clavescens Br. & Sch. (*F. clavescens* Schw.) Similar to *F. hygrometrica* only more robust, being one to $2\frac{1}{2}$ times all dimensions. Dixon says that this is a luxuriant form of the preceding species developed under moist conditions. Reported from "Ohio" by Lesquereux.

4. DISCÉLIUM Brid.

Protonema persistent; gametophytes practically stemless, scales ecostate; calyptra splitting down one side and usually remaining attached to the seta; sporangium operculate. Unisexual.

Discelium incarnata Schw. (*D. nudum* (Dicks.) Brid.; *Bryum nudum* Dicks.; *Weisia incarnata* Schw.) Protonema brown; gregarious, gametophores almost microscopic, bud-like; scales entire, ovate; seta brown, one-half to one inch long, twisted when dry, sporangium zygomorphic, globose, inclined to horizontal. On clay or sandy banks. Lake and Delaware.

EPHEMERACEÆ.

Sporangium non-operculate; minute plants on soil; costa usually present, scales linear to obovate; sporangium immersed, sub-globose, cleistocarpous; protonema usually persistent.

1. Scales lanceolate; green protonema persistent.....*Ephemerum*
1. Scales ovate; protonema not persistent..... 2
2. Scales erect; stalk none; costa percurrent or excurrent.....*Acaulon*
2. Upper scales rosette-like and spreading, stalk long or short, costa ending below the apex.....*Physcomitrella*

1. EPHEMERUM Hampe.

Green protonema persistent; upper scales elongate lanceolate to linear; sporangium globose and apiculate; fruiting in autumn.

1. Scales ecostate, strongly serrate.....*E. serratum*
1. Scales costate..... 2
2. Costa ending at or below the apex.....*E. cohaerans*
2. Costa excurrent, scales gradually long-acuminate.....*E. crassinervum*

Ephemerum serratum (Schreb.) Hampe. (*Phascum serratum* Schreb.) Minute, protonema green and abundant; scales lanceolate to linear, erect, margin coarsely serrate; sporangium globose, apiculate, submerged, brown, glistening. Unisexual. Autumn. Bare soil. Cuyahoga County.

Ephemerum cohaerans (Hedw.) Hampe. (*Phascum cohaerans* Hedw.) Minute, densely gregarious; scales erect-spreading, oblong-lanceolate to ovate-lanceolate, slender, long-acuminate, strongly serrate. Reported by Jennings as occurring in Ohio.

Ephemerum crassinervum (Sch.) Muell. (*Phascum crassinervum* Schw.) Minute, gregarious; scales linear-lanceolate, erect-spreading, long-acuminate, coarsely serrate above; seta short, sporangium immersed, globose, apiculate, half-covered by the calyptra. Unisexual. Late autumn and early spring. On wet and swampy soil in open fields. Reported by Jennings as occurring in central Ohio.

2. ACAULON Muell.

Green protonema not persistent; plants fruit mainly in the spring; scales broad-ovate, crosce-denticulate at the tip, smooth, margins more or less revolute; sporangium not at all or only slightly apiculate, sub-globose, immersed; spores numerous.

1. Uppermost and perichaetial scales carinate, reflexed.....*A. triquetrum*
1. Uppermost and perichaetial scales concave, plane.....*A. rufescens*

Acaulon triquetrum (Spruce.) Muell. (*Sphaerangium triquetrum* Schimp.; *Phascum triquetrum* Spruce.) Gregarious, minute, gametophores bulbous, pale green or yellowish; scales broadly ovate, deeply carinate, reflexed, irregularly denticulate above, costa excurrent, apiculate, recurved; seta arcuate; sporangium globose, smooth. Early spring. Sandy soil. Reported from Ohio by Jennings.

Acaulon rufescens Jaeg. (*Phascum rufescens* Kindb.) Minute, bulbiform, yellowish-green; upper scales deeply concave, margins plane, irregularly denticulate at the apex, costa excurrent into a recurved

apiculus; seta and sporangium as in *A. triquetrum*. Moist clay and sandy soil. No specimen. Reported as common in the central states by Lesquereux and James.

3. PHYSCOMITRÉLLA Br. & Sch.

Protonema not persistent, fruiting mainly in the spring; scales spreading, rosette-like, dentate or serrate, not crisped when dry, smooth, margins plane or involute; sporangium globose to ovoid, non-apiculate, calyptra campanulate.

Physcomitrella patens (Hedw.) Br. & Sch. (*Phascum patens* Hedw.) Gregarious, pale green; scales lance-ovate to oblong or oval, short acuminate, serrate above, costa ending below the apex; seta short; sporangium globose, brownish, immersed or slightly emergent, usually splitting equatorially, obtusely apiculate; antheridia sessile in the upper axils. Paroicous. Autumn. Wet clay and sandy soil on banks or bottoms of streams. Lesquereux and James lists it as "not rare in Ohio."

SCHISTOSTEGACEÆ.

Plants small, about one-fourth inch tall, slender, sterile stalks with scales distichous, their bases confluent; fertile ones with a tuft of scales; scales ecostate; sporangium minute, erect.

1. SCHISTOSTEGA Mohr.

Gregarious annuals, propagating often by brood bodies on the protonema. Unisexual.

Schistostega pennata (Hedw.) Hook & Tay. (*S. osmundaceae* Mohr.; *Gymnostomum pennatum* Hedw. *Mnium osmundaceum* Dick.) "Luminous Moss." Protonema persistent and abundant, green and glistening; seta erect, very slender, sporangium globose, operculate, no stomata, peristome none. Spring. Fruits sparingly. Crevices and dark holes in rocks or the ground. Reported from Geauga County.

SPLACHNACEÆ.

Scales not papillose; hypophysis usually wider than the sporangium peristome single; growing on decaying animal matter.

1. SPLACHNUM (L.) Hedw.

Loose tufts, light to yellowish-green; scales obovate to broad-lanceolate; seta long, sporangium cylindrical to ovoid, 16 peristome teeth, usually reflexed when dry.

Splachnum ampullaceum (L.) Hedw. Stalks slender, one-half to one inch tall; scales distant, lanceolate, acuminate, coarsely serrate, red at the base when old, costa percurrent or nearly so; seta red, 1 to 2 inches long; hypophysis much wider than the sporangium, narrowing to the seta below, smooth, wrinkled when dry, purplish; sporangium brownish-yellow. Summer. Reported by Lesquereux and James as being found in the cranberry swamps of Ohio.

SEX-LIMITED CHARACTERS IN HETEROSPOROUS SPOROPHYTES.*

JOHN H. SCHAFFNER

It appears that sex-limited characters and sexual dimorphism have in the past been considered mostly from the animal side of the subject. For this reason it was thought advisable to give a brief account of some of the more common species which show dimorphism in the sporophyte. The gametophytes of homosporous plants also often show decided sexual dimorphism and the gametophytes of the heterosporous plants exhibit the most extreme dimorphism of any organisms, whether plant or animal.

In order to get a correct understanding of sex-limitation it is best to study sex-limited characters in monocious plants first; for in this case the factors involved can be had in the homozygous condition and the sexual state arises directly from a neutral condition in the vegetative tissues. There are also no allosomes to complicate conditions. In monocious plants the two types of flowers may be commingled in the same inflorescence as in *Aesculus glabra* or in different parts of the same inflorescence, or the inflorescences may themselves be monosporangiate and variously distributed or related to each other on the plant. Two characteristic types are the following: 1st. The staminate flowers are developed first, the inflorescence axis passing from the neutral to the male condition and later this male condition is reversed, passing thru a neutral condition over to the female condition when carpellate flowers are developed. This is the androgynous condition, as in *Carex trisperma*, *Ricinus communis*, and *Zizania aquatica*, and the progression of sexual states corresponds to the normal progression in the flower axis itself. 2nd. The carpellate flowers are developed first and the inflorescence axis changes later from the female state thru a neutral condition, to the male state when staminate flowers are produced above. This is the gynandrous condition and is just the opposite of what normally takes place in the flower axis itself of angiosperms. Examples are *Carex capita*, *Sagittaria latifolia*, *Peltandra virginica*, and *Typha latifolia*. Unfortunately these terms, or at least the first one, have been used in exactly the opposite sense in descriptive botany to designate position on the inflorescence axis.

* Papers from the Department of Botany, The Ohio State University, No. 170.

But it would be very confusing to say that an inflorescence or a plant was androgynous in the genetic sense when the carpellate flowers because of the female condition come first. And it is becoming more evident continually that the dead biology of the past must give way to a "living" or dynamic biology. The terms proterandrous and proterogynous are not available since they refer rather to ripening of the pollen and stigma than to the time of the development of the sporophylls on the axis.

It is evident from the sexual conditions in monocious and hermaphroditic plants that sex-limitation is not a matter of dominance and recessiveness but rather of activity and latency thru the influence of the given sexual state. With the change in sexual state in some part of the body the suppressed factors become active whenever the proper differentiation stage is attained.

Sex-limited characters in the lowest types of heterosporous sporophytes appear only in the sporangia or their stalks. In the second stage of evolution, dimorphisms appear in the sporophylls themselves and as a general rule the diversity increases with the higher types. In the third stage sexual dimorphisms appear between the staminate and carpellate flowers outside of the sporophylls themselves, and the same kinds of differences are to be observed between the flowers whether the plants are monocious or diecious. The fourth stage of evolution of dimorphism shows differences in entire inflorescences; and in the fifth step the sex-limited characters show also in the leaves and stems some distance beyond the inflorescences. In the sixth and extreme case, present typically only in diecious plants all parts of the body may show dimorphic characters in relation to sex.

Sex-limited characters, when they appear on unisexual individuals, have in the past played a prominent part in fantastic speculations on evolution by sexual selection. But when it is realized that the same dimorphisms appear in the sexually differentiated parts of hermaphrodites and monocious species and that the most extreme dimorphisms are to be found in plants which have neither eyes nor the nervous equipment with which to make a choice the whole subject of sexual selection can be easily relegated to the domain of fairyland.

Below is given a small list of the various types of sex-limited characters in heterosporous sporophytes to show the general nature of such characters in the higher plants. For sex-limited characters due to allosomes and characters which show a pecul-

iar migration or transmission because their factors are allosome-linked altho not necessarily sex-limited, one must at present go to the animals.

PLANTS WITH BISPORANGIATE SPOROPHYLLS OR WITH BISPORANGIATE FLOWERS.

1. *Marsilea quadrifolia*—Microsporangia with long, slender stalks; megasporangia with short, robust stalks.
2. *Selaginella kraussiana*—Microsporophyll with a smaller, acuminate blade; megasporophyll with a larger, acute blade.
3. *Aquilegia canadensis*—Carpel covered with hairs, stamen glabrous.

Small differences in character expressions of this nature are almost universal in the sporophylls of seed plants.

MONECIOUS PLANTS.

1. *Taxodium distichum*—Dimorphic inflorescences; staminate cones numerous in a slender catkin-like panicle, carpellate cones few in a small terminal cluster.
2. *Larix laricina*—Staminate flowers pale yellow, carpellate flowers rose-red; stamens and carpels structurally different.
3. *Pinus sabiniana*—Staminate flowers yellow, carpellate flowers dark purple; stamens without a special outgrowth, carpels with a special ovuliferous scale.
4. *Pinus radiata*—Staminate flowers yellow, carpellate flowers dark purple; stamens without a special outgrowth, carpels with a special ovuliferous scale.
5. *Limnobium spongia*—Staminate flowers long-peduncled; carpellate flowers sessile or with a short peduncle.
6. *Cocos nucifera*—Staminate flowers with apocarpous vestigial carpels, small sepals, and narrow petals; carpellate flowers syncarpous with very large broad sepals and broad petals.
7. *Zizania aquatica*—Lemma of staminate flower without an awn; lemma of carpellate flower with a long awn.
8. *Tripsacum dactyloides*—Carpellate part of inflorescence with modified rachis with the spikelets in deep pockets; staminate spikelets on an ordinary rachis.
9. *Euchlaena mexicana*—Decided differences between the staminate and carpellate inflorescences and their bracts; carpellate rachis extremely modified into pockets.
10. *Zea mays*—Decided sexual dimorphism between the two inflorescences and the internodes and their leaves below.
11. *Liquidambar styraciflua*—Carpellate flowers in a simple spherical head; staminate flowers in racemose clusters.
12. *Sarcobatus vermiculatus*—Staminate flowers without a calyx in scaly spikes; carpellate flowers with a compressed calyx, sessile and solitary.
13. *Eurotia lanata*—Staminate flower with a four-parted calyx; carpellate flower with two united bracts covered with long hairs.
14. *Quercus* sp. Staminate flowers without involucre, in long flexible catkins; carpellate flowers solitary or clustered, with a prominent expanded cup and involucre.

15. *Alnus* sp.—Staminate and carpellate catkins and their bracts decidedly different.
16. *Ostra virginica*—Bracts of the staminate and carpellate inflorescences decidedly dimorphic.
17. *Carpinus caroliniana*—Bracts of the staminate and carpellate inflorescences different.
18. *Juglans nigra*—Carpellate flowers solitary or several in a cluster at the end of a short peduncle; staminate flowers in long flexible catkins.
19. *Hicoria* sp.—Inflorescences with dimorphisms similar to *Juglans*.
20. *Croton capitatus*—Staminate flowers racemose with a 5-parted calyx and 5 petals; carpellate flowers sessile, with 7-12 sepals and no petals.
21. *Littorella uniflora*—Staminate flowers on slender scapes; carpellate flowers sessile.
22. *Cyclanthera dissecta*—Staminate flowers racemose on long peduncles; carpellate flowers solitary on very short peduncles.
23. *Sicyos angulatus*—Staminate flowers corymbose or racemose on a long peduncle; carpellate flowers capitate on a shorter peduncle.
24. *Ambrosia* sp.—Carpellate and staminate heads decidedly dimorphic.

EXAMPLES TO SHOW THAT SEX-LIMITED CHARACTERS ARE SIMILAR
IN MONECIOUS AND DIECIOUS SPECIES.

1. *Naias flexilis*, monocious—Carpellate flower without a spathe, staminate flower with a double spathe or sheath.
2. *Naias marina*, diecious—Flowers of the same nature as in the monocious species.
3. *Carex lupulina* and most other species, monocious—Carpellate flowers with a sack-like perigynium; staminate flowers without a perigynium.
4. *Carex dioica*, diecious—Carpellate and staminate flowers of the same nature as in the monocious species.

DIECIOUS PLANTS.

1. *Cycas revoluta*—Staminate and carpellate plants with very extreme sex-limited characters. Carpellate plant flowerless, the carpels in a rosette, staminate plant with determinate cones. Carpels with a compound leaf blade, stamens simple.
2. *Taxus canadensis*—Carpellate flower with one reduced carpel; staminate flower with 5-8 stamens.
3. *Hydrocharis morsus-ranae*—Flowers decidedly dimorphic, the staminate and carpellate flowers on two different evolutionary levels. Staminate flower with 3 vestigial, apocarpous carpels, 9 stamens and 3 staminodes, hypogynous; carpellate flower with 6 syncarpous carpels and only 6 vestigial epigynous stamens.
4. *Vallisneria spiralis*—Carpellate flower solitary and large on a very long, spirally coiled peduncle by which the flower reaches the surface; staminate flowers minute, many on a very short peduncle, the individual flowers separated by an abscission layer and floating free on the surface.
5. *Phoenix dactylifera*—Decided dimorphism between the perianths of the staminate and carpellate flowers.

6. *Distichlis spicata*—Rachilla continuous in the staminate spikelet and the spikelets more numerous than in the carpellate inflorescence; rachilla of the carpellate spikelets articulated and the spikelets fewer in the inflorescence.
7. *Bulbilis dactyloides*—Decided dimorphism between the staminate and carpellate inflorescences and spikelets.
8. *Spinifex hirsuta*—With decided sexual dimorphism of the inflorescences.
9. *Similax herbacea*—Perianth segments of the staminate flowers larger than those of the carpellate flowers.
10. *Arisaema triphyllum*—Peduncle of the carpellate inflorescence much more persistent than that of the staminate inflorescence.
11. *Dioscorea villosa*—Carpellate inflorescence a simple catkin-like spike with few flowers; staminate inflorescence a branched panicle, the branches slender and spike-like with numerous flowers.
12. *Thalictrum dioicum*—Sepal of the carpellate flower about twice as long and wide as of the staminate flower, oval or obovate, while the sepal of the staminate flower is narrowly ovate and with a somewhat narrowed tip.
13. *Mercurialis annua*—Staminate flowers in elongated axillary spikes or racemes; carpellate flowers in the axils of the leaves.
14. *Carica papaya*—Inflorescence and flowers decidedly dimorphic; staminate flowers sympetalous in large, much branched inflorescences; carpellate flowers choripetalous in small slightly branched inflorescences or solitary.
15. *Papyrus papyrifera*—Staminate flowers in cylindric ament-like spikes; carpellate flowers capitate.
16. *Cannabis sativa*—Both the vegetative parts and the flowers with decided sexual dimorphism. In winter-grown hemp second internode of staminate plants about twice as long as that of carpellate plants.
17. *Humulus japonicus*—Both the inflorescence and the vegetative parts of the flowers show decided sexual dimorphism.
18. *Baccharis halimifolia*—Heads of the staminate and carpellate plants dimorphic.
19. *Anaphalis margaritacea*—Staminate and carpellate corollas dimorphic.
20. *Antennaria plantaginifolia*—Involucral bracts, pappus bristles, and corollas of the staminate and carpellate heads strongly dimorphic.

VESTIGIAL SPOROPHYLLS.

Below are given brief lists of some of the species studied by the writer to show the four possible types of distribution of vestiges of the opposite sporophylls in monosporangiate flowers. Cases in which vestiges are present in one flower and not in the other are to be regarded as sexual dimorphisms or sex-limited characters the same as dimorphisms in the vegetative parts; for the experiments on hemp and other plants show that the potentialities for both sporophylls are present

even when there is no vestige whatever expressed under normal conditions.

1. Monocious and diecious plants with sporophyll vestiges in both staminate and carpellate flowers—*Sagittaria latifolia*, monocious; *Phoenix dactylifera*, diecious; *Cocos nucifera*, monocious; *Zizania aquatica*, monocious; *Tripsacum dactyloides*, monocious; *Asparagus officinalis*, diecious; *Hydrocharis morsur-ranae*, diecious; *Chamaelirium luteum*, diecious; *Dioscorea villosa*, diecious; *Musa sapientum*, monocious; *Gymnocladus dioica*, diecious; *Lychnis alba*, diecious; *Acer platanoides*, diecious; *Rhus glabra*, diecious; *Acer saccharinum*, diecious; *Schmaltzia crenata*, diecious; *Coix lacryma*, monocious; *Sassafras sassafras*, diecious; *Ailanthus glandulosa*, diecious; *Ptelia trifoliata*, diecious; *Rumex altissimus*, monocious; *Aruncus aruncus*, diecious; *Platanus occidentalis*, monocious; *Aesculus glabra*, monocious; *Cucumis sativus*, monocious; *Diospyros virginiana*, diecious; *Silphium integrifolium*, monocious.

2. Monocious and diecious plants with stamen vestiges in the carpellate flowers but without a vestige of the gynecium in the staminate flowers—*Vallisneria spiralis*, diecious; *Smilax hispida*, diecious; *Peltandra virginica*, monocious; *Zantedeschia aethiopica*, monocious; *Menispermum canadense*, diecious; *Napea dioica*, diecious.

3. Monocious and diecious plants with carpel vestiges in the staminate flowers but without stamen vestiges in the carpellate flowers—*Tumboa bainesii*, diecious; *Carica papaya*, diecious; *Ambrosia trifida*, monocious; *Rumex acetocella*, diecious; *Amaranthus retroflexus*, monocious; *Morus alba*, diecious.

4. Monocious and diecious plants with no vestigial sporophylls normally either in the staminate or carpellate flowers. In general none of the primitive types of flowers like *Pinus*, *Zamia*, or *Juniperus* show any indication of the opposite type of sporophylls and frequently the extreme types of monocotyls and dicotyls also show no such vestiges. Occasionally low types of diecious angiosperms also show no vestiges like the diecious or partially diecious *Thalictrums* altho they have plainly been derived from bisporangiate ancestors like the *Thalictrums* with bisporangiate flowers—*Alocasia odorata*, monocious; *Arisaema triphyllum*, diecious; *Typha latifolia*, monocious; *Carex* sp., monocious and diecious; *Thalictrum dioicum*, diecious; *Cannabis sativa*, diecious; *Humulus japonicus*, diecious; *Acer negundo*, diecious; *Populus deltoides*, diecious; *Begonia* sp., monocious; *Sicyos angulatus*, monocious.

DEVELOPMENT OF THE MALE GONOPODS AND LIFE HISTORY STUDIES OF A POLYDESMID MILLIPEDE.*

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INTRODUCTION

The gonopod of the male millipede is at present the chief diagnostic character in identifying species. Therefore the development of these structures is interesting and important in the study of the millipede group.

For a study of this development *Euryurus erythropygus* (Brandt), a Polydesmid millipede, was chosen because they were found in abundance and thrived in the laboratory.

Since so little is known regarding the life-history and habits of the Polydesmidae or of the millipedes in general, opportunity was taken to study certain anatomical features; copulation; oviposition; characteristics of the eggs and the post-embryonic development. With regard to the latter the instars in the life-history were determined; studies made of ecdyses and of the cocoons. The cocoons are hollow, somewhat spherical chambers in which ecdyses of the instars occurs.

The research upon which this report is based was carried on chiefly at Miami University, Oxford, Ohio, during the school year 1924-1925. Observations were continued at The Lake Laboratory, Put-in-Bay, Ohio, and at The Ohio State University.

Grateful acknowledgment is made to Dr. Stephen R. Williams of Miami University, for direction of the work, and to Dr. Raymond C. Osburn, of The Ohio State University, for advice and criticism.

MATERIALS AND METHODS

While collecting Myriapods in Ohio, near Oxford, during the latter part of September and in October, 1924, it was observed that specimens of *Euryurus* were abundant in the

* Portion of a thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science (1925).

heartwood of much decayed logs, in moist and more decayed wood, usually sapwood, and under decaying wood if rather moist conditions prevailed. With a hope that they would breed and endure captivity in the laboratory, the specimens collected were placed in glass receptacles approximately five and one-half inches in diameter and three and one-eighth inches deep. These were half filled with small broken up pieces of moist and much decayed sapwood from an old rotten log and a little humus. A layer of vaseline was spread around the rims of the receptacles and glass covers placed over them,

TABLE I.

STAGES FOUND, MEAN MEASUREMENTS OF WIDTH AND LENGTH OF THREE INDIVIDUALS OF EACH STAGE, NUMBER OF SEGMENTS AND PAIRS OF LIMBS ON EACH SEGMENT.

Stages	Number of Segments	Number of Pairs of Legs		Length in Millimeters	Width in Millimeters
		Male	Female		
1st larval stage.....	7	3	.....	1.32	.345
2nd larval stage.....	9	6	.....	2.13	.556
3rd larval stage.....	12	11	.....	3.47	.916
4th larval stage.....	15	16	17	5.91	1.15
5th larval stage.....	17	22	23	8.46	1.72
6th larval stage.....	18	26	27	12.4	2.20
7th larval stage.....	19	28	29	19.3	3.30
8th stage (adult).....	20	30	31	29.1	4.13

Width—distance between the lateral edges of the tergites.

Length—distance from forehead to tip of anal segment.

All the animals measured were males except possibly some females among those individuals of the first three larval stages where it was impossible to distinguish sex.

thus insuring very little, if any, evaporation. However, a few drops of water were added occasionally and moisture and other conditions were kept as natural as possible. Some of the receptacles were opened every day, others nearly as often, for observations and fresh air entered at these times. Later observations indicate that this exchange is not frequently necessary because some receptacles were not opened often but the animals appeared to thrive as well as others. *Euryurus* is therefore easily kept in captivity and breeds and thrives in the artificial environment described. A number reared in the laboratory survived during the summer and during most of the fall of 1925, at The Ohio State University. The humus

and small pieces of decayed sapwood, placed in the receptacles, were examined carefully for contaminating forms, such as other Millipedes, centipedes, mites, earthworms, eggs, insect larvae, pupae, etc., and those found were removed. However, enchytraeid worms, some earthworms, craneflies, thysanura, mites, ticks and a few beetle larvae were later found in some of the receptacles so the elimination was not complete. Adult males and females observed copulating and, in some cases males and females not pairing, were isolated in separate receptacles. In most of the jars the females laid eggs and these were permitted to hatch in the same receptacle with the adults. As soon as the larvae started emerging from the eggs, a number of the small specimens were placed in Petri dishes in order to observe their habits more accurately. An abundance of material was available for study. Observations of the larvae were continued through their metamorphosis, thus the larval stages in the life history were determined and certain other observations recorded.

In studying the development of the gonopods at least three individuals of each stage were used,—in most cases more—and the gonopods of each stage when possible were examined in the following ways:—(1) Many dissections of each of the different stages in the development were made, dehydrated, cleared and mounted on slides. In the earlier stages, especially, it was not possible to study the gonopods carefully without doing this. (2) The gonopods were dissected from a number of freshly killed individuals in stages seven and eight and drawn without mounting. (3) All the steps in the developing gonopods were also studied in place on freshly killed individuals.

Camera lucida drawings, made at different levels by focusing, were put together to indicate the form of the structures studied. There were variations but, in general, the pattern was nearly uniform. When possible the mounted structures were studied under the high power objective.

Photographs were taken of larval stages and the adult; of some incomplete and completed cocoons, which are hollow, somewhat spherical chambers in which ecdyses of the larval stages occurs; of the cast chitin of an animal which had completed ecdysis from the last larval stage to the adult.

SYNONYMY AND DISTRIBUTION

Polydesmus erythropygus. Nov.

1839. Brandt, J. F. Note Relative a la classification Des Especies Qui Composent Le Genre Polydesmus.

Polydesmus erythropygus.

1841. Brandt, J. F. Recueil, 134.

Euryurus maculatus.

1847. Koch, System d. Myriap., 138.

Polydesmus (*Paradesmus*) *carolinensis*.

1859. Saussure, Linnea Entomologica XIII, 325.

Euryurus maculatus.

1863. Koch, Die Myriapoden. Bd. 1, 7 to III, fig. 8.

Polydesmus Subgenus *Paradesmus erythropygus*.

1865. Wood, Trans. Am. Phil. Soc. XIII, 218.

Euryurus erythropygus.

1888. Bollman, Notes on a Coll. of Myriapoda from E. Tennessee, Ann. N. Y. Ac. Sci. X, pp. 106-112.

E. erythropygus—Common in E. Tennessee (Beaver Creek), Proc. U. S. Nat. Mus., XI, pp. 339-342. Notes on a Coll. of Myriapods from Mossy Creek, Tennessee.

E. erythropygus—Common. Cat. of Myriapods of Ind. Proc. U. S. Nat. Mus., XI, pp. 403-410.

E. erythropygus—Abundant. Notes on the N. Am. Myriapods described by C. L. Koch.

E. maculatus Koch. Syst. Myr., 138, 1847 (? habitat); Die Myr., 1, 7, pl. 3, fig. 8, 1863. According to Peters *maculatus* is the same as *E. erythropygus* (Brandt).

Distribution of *Euryurus*

From the literature that was accessible *Euryurus* is known only from Africa and the United States of America. A list of this literature is included in the Bibliography.

Dr. C. L. Koch, ('63), reports the country unknown.

H. C. Wood, ('65), *Euryurus erythropygus* is found in Western Pennsylvania and Illinois.

Dr. R. Latzel, ('84), reports it for Africa and America.

Bollman, ('93), gives the following data concerning the habitat of this species:— (a) Common in Tennessee at Beaver Creek, Jefferson Co., East Mossy Creek. (b) Abundant in Indiana at Bloomington, Boswell, La Fayette, Kokomo, Westfield, Terre Haute, Greencastle, Mitchell, Salem, New Providence, Brookville, Wyandotte.

In 1924-1925, the writer found the animals abundant in southwestern Ohio, near Oxford, in Butler County.

DESCRIPTION.

The body is convex on its dorsal and ventral surfaces and in the adult is made up of twenty body segments besides the head. They can roll up into a spiral but not into a ball. The tergites are elevated in the middle, more so in the female than the male. The body segments, with the exception of the first, are entirely fused into a ring, that is, the tergites are fused with their appropriate pleurites and these with the appropriate sternites. This is characteristic of the *Polydesmidae*. The first sternum alone is free. The body is hard, the dorsal side smooth, shining and naked, with brilliant orange spots. There is a rather large semicircular orange spot on the posterior edge of each of the tergites. The orange color varies in intensity, in some it is deep orange, in some light.

This color bleaches out almost or entirely in alcohol or if allowed to dry. On each tergite olive-chestnut colored areas are arranged around the orange spots. The color becomes darker toward the maculae. The keels or lateral edges of the tergites are colored orange. These keels or edges of the body segments are very prominent, wing-like and powerfully developed and the prominent longitudinal ridges found on them bear the repugnatorial pores. These pores are found on the keels of segments 5, 7, 9, 10, 12, 13, 15, 16, 17, 18, 19 and are surrounded by long oval swellings on the dorsal side of the keels. The keels of the four segments next to the last and the first five behind the head are crowded together so that they slightly overlap each other.

The mandibles present on the side of the head project like cheeks. One pair of maxillae is present. They have united to form a well developed lower lip, the gnathochilarium. No maxillipedes are present.

The head is smooth, hard and shining and a rather deep dorso-ventral cross furrow was observed on the olive-colored forehead in the middle above the level of the bases of the antennae. The animal is eyeless. The antennae are short and are composed of eight antennal joints in adults.

In most individuals there is a well marked black, median line along the dorsum. This is especially noticeable in the larval stages before the pigment develops and in individuals of a slate color. In larval stages the margins of the lateral carinae appear faintly orange in the third moult before the

adult in some specimens. Gradually the color increases and the chestnut and olive and slate colors appear in the stage preceding the adult. The ventral side and the legs are dull yellow in color. After drying for a while or if preserved in alcohol or glycerine or a mixture of both, they become a yellowish brown color.

The legs are somewhat hairy but without special characteristics. The eighth pair of legs specially modified as gonopods are present on the seventh sternite of the male of all except the first three larval stages, in which they have not yet appeared. The paired openings of the vasa deferentia are found on projections located on the coxal joints of the second pair of legs. Genital structures (vulvae) are found in a somewhat similar position attached near the base of the second pair of legs in the female.

The anal segment is quadrate, trapezoidal and broad. There is an anal plate on either side of the anal opening. The anal scale is broad and rounded posteriorly. It is rather large and tapers and a few hairs project from its ends and sides. There is an orange spot on its posterior margin.

Some conclusions regarding differences between adult males and females.

1. Females were more numerous than males.
2. The legs of males are slightly longer than those of the females.
3. Females thicker dorso-ventrally than males.
4. Females slightly longer than males.
5. Females slightly wider than males.
6. Chestnut color of females often darker than that of males.
7. The longitudinal ridges along the keels of the males appear to be more prominent than on the females.
8. Females have thirty-one pairs of legs, vulvae developed on the second pair.
9. Males have thirty pairs of walking legs with sex organs opening on the coxapods of the second pair and the eighth pair modified into gonopods or copulatory organs.

LIFE HISTORY

(a) Description of copulation.

In copulation the male is usually above the female and with dorsal surface up and head bent over the anterior part of the female which is usually below with ventral side up in contact with the ventral side of the male. The anterior legs of the male are used to clasp the female, hooking over the keels or edges of the tergites. The gonopods enter the vulvae of the female.

(b) Observations concerning the eggs:

(1) Oviposition.

In most cases the females laid their eggs in cavities made by themselves a short distance below the surface of the soil. Under natural conditions the eggs have been observed in small cavities in much decayed logs.

(2) Numbers laid.

Under artificial conditions in the laboratory, in one case 526 eggs were counted. On April 18, 1925, while collecting, a single nest of eggs was found in a small cavity. The nest was brought in with extreme care, and found to contain 586 eggs.

(3) Size, shape, color, coating.

The eggs are very small and coated with a glutinous fluid which causes them to adhere in clusters. They are usually spherical, and greenish yellow in color, but some oval, some opaque and some brown eggs were found. The usual diameter of oval eggs was from .44 to .45 mm., and the length .53 to .534 mm.; the dimensions of the spherical ones .516 to .518 mm. by .520 to .524 mm.

(4) Constitution:

Myriapod eggs, according to Korschelt and Heider ('99, vol. 3, p. 219) "are very rich in yolk and are surrounded by a vitelline membrane and another structureless but firmer envelop, the chorion, which is apparently secreted by the genital ducts." This description may be applied to the eggs of *Euryurus*. The egg envelop was observed when split and the young forms were about to emerge.

(5) Time of hatching:

- (a) Laid October 4, 1924; hatched Nov. 8 (36 days).
- (b) Laid October 31, 1924; hatched Dec. 17. (48 days.)

(c) Laid December 19, 1924; hatched Jan, 28, 1925. (41 days.)

Eggs collected in their natural environment and brought to the laboratory April 18, 1925, were hatched by May 16. (29 days.) Time of laying not known.

In one case not observed as closely as the above, a male and female were observed copulating December 17, 1924, and were placed in a separate receptacle. The eggs were not observed but sixty-five days later on February 19, 1925, individuals of the first larval stage were found. In another similar case sixty-eight days elapsed. In the latter case the weather was colder.

(c) Post-embryonic development.

(1) The stages, ecdyses, intervals between them and cocoon building.

Stages

The larvae of *Euryurus* apart from the smaller number of segments and lack of pigment in the earlier stages, does not differ greatly in form from the adult. The first larval stage possesses three pairs of legs. According to Korschelt and Heider ('99, vol. 3, p. 236), "The possession of three pairs of legs by the first larval stage brings about a striking resemblance to an insect larva. This is, of course, merely an external resemblance, for, in the first place, the homology of the cephalic regions of the insects and the Myriapods (in respect of the number of segments utilized in the formation of the head), is still very doubtful, and further in the latter, one of the anterior trunk segments, usually the second, is, as a rule, devoid of extremities, so that the first three pairs of legs are distributed on four segments, whereas the thorax of the Insects, as is well known, consists of three segments, each possessing a pair of limbs."

In the post-embryonic development of *Euryurus* the additions are in the form of the double segments characteristic of the Diplopoda.

(Korschelt-Heider '99, Vol. 3, pp. 237-238) "The formation of new somites always takes place between the anal segment and that last developed (Latzel), and the formation of double segments is now proved to be due to the fusion of two of the originally distinct primitive segments (Heathcote.) The six-

limbed larvae has several other pairs of legs as rudiments beneath the integument. The number of these varies in different forms. It is characteristic of the terminal segment in the Diplopoda that no fusion takes place in it, and this is also the case with the four anterior segments (known as the thorax), and, apparently, fusion is also absent in the genital segment."

The post-embryonic development of *Euryurus*, as shown in the table given on page 26, is characterized by seven moults. Fig. 6 is a picture of the larval stages and the adult stage. A single pair of legs is found on the first, third and fourth trunk segments of all the stages, the second trunk segment lacks limbs in every case in *Euryurus*. Sexual maturity is reached in the eighth stage. Adults have not been observed to moult. Besides the single pairs of legs on the first, third and fourth trunk segments of the first larval stage, two truncated pairs of legs are found lying below the integument, belonging to the fifth segment and a single pair of the same kind the sixth segment. These limbs project freely after ecdysis. No intermediate sizes between the stages were found.

The post-embryonic development of *Euryurus* as observed by the writer, is similar to that of the genus *Polydesmus*, given by Drs. R. Latzel and O. vom Rath, except that for the third stage they have recorded observing ten pairs of legs for males and eleven pairs for females. The writer examined carefully sixty-six individuals of the third larval stage of *Euryurus*, and found all of these to possess eleven pairs of legs.

Fifty-six of these individuals examined were reared in the laboratory. On April 20, 1925, ten forms collected April 18, 19 , from their natural environment, were inspected and all of these had eleven pairs of legs. As females are more numerous than males in this species, there was the possibility that all the animals examined having eleven pairs of legs were females. Eight specimens, each having eleven pairs of legs, were isolated in a Petri dish in which soil had been placed, which had been carefully examined to make sure that no other *Euryurus* larvae were present. After ecdysis had occurred, two were found which had sixteen pairs of legs, this distinguishing them definitely as males and six were found possessing seventeen pairs of legs distinguishing them as females. This is conclusive evidence that all of the sixty-six individuals previously examined, were probably not females. Ten individuals of the third larval stage of *Oxidus* (*Paradesmus*) *gracilis*, another Polydesmid,

were examined and no individuals with ten pairs of legs were found. None of this species were reared to the next stage.

Eggs of *Polydesmus serratus* were collected under natural conditions (April, 1925), and brought in and hatched in the laboratory. Eight individuals reaching the third larval stage were carefully examined by Dr. Williams and myself, and all eight were found to possess eleven pairs of legs. These were isolated in a glass container and brought to the Lake Laboratory and there reared to the next stage, in which the first individual examined had sixteen pairs of legs, thus distinguishing it as a male.

Ecdysis.

Euryurus attains its full sexual character after seven moults, in each of which the chitinous cuticle is entirely thrown off and replaced by a new one secreted by the epidermis or hypodermis just under it. The exoskeleton is shed after each larval stage, but has not been observed to be shed by adult animals. Ecdysis is performed at intervals in the larval stages.

TABLE SHOWING THE SHORTEST AND LONGEST TIMES OBSERVED FOR THE INSTARS OR STAGES BETWEEN ECDYSES.

1st Instar.....	5 to 14 days
2nd Instar.....	14 to 20 days
3rd Instar.....	22 to 24 days
4th Instar.....	26 to 30 days
5th Instar.....	31 to 34 days
6th Instar.....	41 to 41 days
7th Instar.....	44 to 47 days
Hatching of Eggs.....	29 to 43 days
<hr/>	
Lengths of life history.....	212 to 253 days

The ecdyses of individuals in cocoons were followed to find out if possible how ecdysis occurs and to look for intermediate steps in the development of the gonopods between stages three and four and seven and eight.

To determine whether moisture is a factor in the length of time for ecdysis, an experiment was performed in which the temperature was fairly uniform but moisture was varied. (a) In one Petri dish individuals of the first larval stage were placed in a rather moist environment. (b) In another dish similar individuals were placed in a considerably drier environment. Animals in the conditions designated in (a) moulted in from 6-8 days. Animals in (b) moulted in from 13-14 days. These results indicate that it takes a longer time for ecdysis

under rather dry conditions. With these cases and others observed other conditions such as temperature and confinement may have also modified the intervals so that they may vary from those occurring under natural conditions.

METHOD OF ECDYSIS DERIVED FROM STUDYING SOME CAST SKINS
OF LARVAL STAGES.

Fig. 7 is a picture of the cast skin of a female which had moulted from the last larval stage to the adult stage. The old chitin had split down the mid-ventral line and also somewhat laterally, just above the attachment of the legs on one or both sides. The dorsal surface seemed intact in this and in other casts observed. The cast was disarticulated at the junction of the head and first segment and the animal must have crept forward, causing the anterior end to crowd together somewhat. This was also noticed in other casts observed.

Cocoon Building.

The larvae of each stage build their cocoons as follows:—Small bits of much decayed wood, or earth are moistened with a sticky fluid, presumably secreted by the salivary glands.

The materials used are worked up with the jaws and front legs and when of a suitable size are placed together. The completed cocoons are shaped somewhat like a hollow sphere (Fig. 9.) The inside is rather smooth and even and the outside is rough. The shape and size of the materials of which it is composed can be readily discerned. A small stack or bluntly rounded chimney-like projection is made and closed up at the top. Indicated by the arrow in Fig. 9. Fig. 8 is a photograph of three cocoons in the process of construction by forms of the seventh larval stage. The one slightly to the left of the center is the result of the work of one individual for about one day and represents the base. The animal was continuing this construction just before this picture was taken. As soon as disturbed it disappeared. The small bits of materials are put into place from the inside and the individuals work around. The other two cocoons in the picture are much nearer completion than the one described and represented from two and one-half to three days work. The animal at the base of the upper one on the right was working inside and when interrupted to take the photograph it made a hasty retreat for a millipede, hence the somewhat blurred picture of it. The

cocoons in the photograph were constructed on the upper surface of pieces of rotten wood lying on top of the other material in the glass receptacles and were photographed in place. Some animals in the fifth, sixth and seventh larval stages built their cocoons on the side of the receptacles above the surface of the contents. Fig. 9 is a photograph of two completed cocoons and the animals are enclosed in them. These were built by individuals of the last larval stage. Three and one-half to four days were required for their construction. Dimensions of the upper cocoon:

Width at bottom where attached = 18 mm.

Width of the chimney-like projection = 5 mm.

Height of the whole cocoon, including the chimney = 21 mm.

Notes on the time it takes to build the cocoons in which the last larval stages moult:

A. (1) A female started construction Jan. 12, 1925.

(2) Finished on Jan. 16.

(3) Emerged from the top March 3. (47 days.)

The chimney-like projection was broken off.

Measurements of the cocoon:—

Width at bottom = 17 mm.

Height to the projection = 13.5 mm.

Height of the projection = 4.5 mm.

Width of the projection = 5.0 mm.

B. Cocoon started by a male on Jan. 28, 1925, was completed Jan. 31. This was built along the side of a glass receptacle a short distance above the level of the contents.

Most of the cocoons built by the other larval stages were built below the surface. The animals are very helpless a short time after they close up their cocoons. If a cocoon is opened and the animal disturbed when in the midst of ecdysis no motions can be perceived, indicating that they are absolutely helpless during this process. Near the completion of ecdysis motion is apparent. Presumably the cocoons are built for protection. Three individuals in the midst of ecdyses from stage three to four were observed to be eaten by a beetle larva.

On April 19, 1925, cocoons and larval stages of *Euryurus* were found in their natural environment.

THE DEVELOPMENT OF THE GONOPODS.

The gonopods of the male are modified from the eighth pair of legs on the seventh body segment. With naked eye or with low magnification in all the individuals of the third larval stage examined, the eighth pair of legs appeared to be

most appreciably smaller or otherwise different from the walking appendages. With higher powers of the microscope a measureable difference was found in some individuals after dissecting and mounting the eighth and ninth pairs of legs. In one typical specimen the eighth pair of legs were found to be .559 mm. long and the ninth pair .576 mm. long. It is presumed that the individual from which these were dissected was a male.

In another specimen the eighth pair of legs were .568 mm. long and the ninth pair .571 mm. long. The individual from which these were dissected might possibly have been a female.

In *Euryurus*, according to observations, the modification of the male gonopods, which are found in the place of the eighth pair of legs, appears first in the fourth larval stage. Following are the steps found in the development of the gonopods, with description and measurements of each.

First Step.

On the fourth larval stage in place of each of the eighth pair of legs of the preceding stage, a single joint is found outlined by an oval bounding line. (Fig. 1.) Measurements of the joints = .077 mm.; height = .043 mm.

Second Step.

In the fifth larval stage two joints were found in place of the one found previously. This time the two pairs of these joints are placed symmetrically in a small oval disc. (Fig. 2.) The joints could not be dissected from the disc because of their delicacy so the whole sternite and the ninth pair of legs were mounted. Measurements: Length of oval disc = .292 mm.; width, .112 mm.; first joint, length = .103 mm.; width = .065 mm.; second joint, length = .073 mm.; width = .052 mm.

Third Step.

In the next larval stage, three joints representing each appendage were found in a larger oval disc. (Fig. 3.) Measurements:—length of oval disc = .361 mm.; width = .206 mm.

First joint

Length = .146 mm.
Width = .141 mm.

Second joint

Length = .138 mm.
Width = .123 mm.

Third joint

Length = .103 mm.
Width = .060 mm.

The line across the oval disc, projecting slightly on either side, probably represents a boundary line between sternites.

Fourth Step.

In the last larval stage, each appendage shows three joints as before, but considerably changed and enlarged and for the first time free from the sternite and lying in an oval opening in it. (Fig. 4.) The dotted lines outlining the first joints indicates that the greater part of these lies in a cavity under the sternite. Measurements: length of oval opening = .705 mm.; width of oval opening = .370 mm.

<i>First joint</i>	<i>Second joint</i>	<i>Third joint</i>
Length = .215 mm.	Length = .327 mm.	Length = .292 mm.
Width = .202 mm.	Width = .146 mm.	Width = .258 mm.

The gonopods shown in 4B were dissected from a freshly killed specimen and drawn without mounting. Divisions were observed on the basal joints and are indicated by lines. The shaded areas indicate depressions in the second and third joints. There are cavities opening to the outside designated by a and e. There seemed to be a cavity or hollow space inside the proximal joint of each gonopod when examined from a dorsal view.

In the drawings of mounted gonopods studied under a higher magnification more details could be observed. (Fig. 4A.) The third or distal joint appears to be attached only at the outer edge. In one case examined, the terminal joint showed the structure as indicated by the distal joint (d. j.) on the left gonopod. (Fig. 4A.) A comparison with the adult gonopods, Fig. 5 shows a similarity. Other similar cases were observed. Thus the terminal section of the gonopod is differentiated from the third joint by the breaking away of the wall on the inner proximal corner and then, by straightening somewhat, produces the curved adult distal joint. The proximal joint is large and represents the coxal joint of the appendage enlarged and differentiated. Whether the other joints have been cut off distally from it and certain structures of the adult gonopods in turn developed from these, or the distal joint of the three represents the first step in the development of the gonopod and the other joints have appeared one after the other behind it, is not determined.

The breaks in the chitin shown in Figures 4A and 4B must be in some way connected with the forming of the distal joint which later, by straightening and going laterally, will produce the curved end of the male organ.

Fifth Step.

No intermediate conditions during ecdysis between stages seven and eight were found. Sexual maturity is reached in the eighth stage and is accompanied by the complete copulating appendages as shown in Figures 5, 5A, 5B. The adult gonopods are curiously modified. At the base of each gonopod a large joint is found, known as the coxa copulativa. Dimensions:— Length = .989 mm.; width, = .654 mm. A transverse hook is attached to the inside of each of these, the purpose of which is probably for holding. In some gonopods mounted on slides this appeared tubular. On the concave side of the distal joint of the much curved gonopod is found a hairy elevation, pulvillus piligerus, for the reception of sperm. Immediately distal to this is located a blunt spine. A structure which looks like a tube starts below its proximal end and passes to the end of the long needle-like projection on the terminal curved section of the gonopod. In an endeavor to learn whether this was a tube some dissected gonopods were placed in stain. The stain did not penetrate into this, possibly hindered by capillarity or perhaps there is no passage. In general, the middle joint is narrow as compared to the other two and in some cases is wedge-shaped so that sometimes the proximal and distal joints touch each other on the outer edge. There is a terminal section which curves inward like a swan's neck and is distally bifid. "The forked fingers of these gonopods are long and needle-like and somewhat twisted." (Koch)

Numerous hair-like projections are found on the gonopods as indicated in Fig. 5A.

From the top of the second joint to the tip of the terminal section = 1.46 mm.

The oval opening through which the gonopods project has a rather high sharp edge. Dimensions:— width = .903 mm.; length = 1.25 mm. Specimen 1.

Specimen 2:— width, = .928 mm.; length, 1.29 mm.

Summary of the steps in the development of the Gonopods.

(1) Individuals of the third larval stage and eleven pairs of legs, with a somewhat reduced eighth pair of legs were thought to be males, the others females.

(2) In the next moult the eighth pair of legs have disappeared and in their place two very small joints appear.

(3) The fifth larval stage shows a small oval disc with two joints of each of the gonopods outlined.

(4) The next moult shows three joints on each side in a somewhat larger oval disc.

(5) In the last larval stage these appendages are free from the sternite and lie in an oval opening in it.

The terminal sections of the gonopod differentiate from the third joint by the breaking away of the wall on the inner proximal corner and then by straightening somewhat to produce the adult distal joint.

Proofs that the gonopods are modified from the eighth pair of legs:

(a) Commencing in the fourth stage the males have one less pair of legs than the females. The eighth pair of walking legs is missing in males.

(b) The males in stage three possess eleven pairs of legs the same as the females. In the moult between stages three and four, the eighth pair is lost and the rudiments of the gonopods appear in the fourth larval stage.

SUMMARY.

I. Differences between adult males and females.

1. Females were slightly longer, wider, thicker and more numerous than males.
2. The legs of the males are slightly longer than those of the females.
3. Females have thirty-one pairs of legs with vulvae attached to the second pair.
4. Males have thirty pairs of walking legs with sex organs opening on the coxopods of the second pair of legs and the eighth pair of legs modified into gonopods or copulatory organs.

II. Post embryonic development.

The post-embryonic development of *Euryurus* is characterized by seven moults, with the addition of segments and pairs of limbs as shown in the table on page

III. Ecdysis.

1. *Euryurus* attains its full sexual character after seven ecdyses which are performed at rather short intervals and in cocoons.
2. The time required for ecdysis increases with each later larval stage.

IV. Gonopods.

The gonopods undergo a gradual progression and development from the fourth larval stage on to the adult stage.

BIBLIOGRAPHY.

- BRANDT, J. F.
1839. Note Relative a la Classification des Especies Qui Composent le Genere Polydesmus, et Suivie d'une Caracteristique de Dix Especies Nouvelles, Ainsi Que de Quelques Remarques sur la Distribution Geografique des Especies en General. Extrait du Bull. Scientif. d. l'Acad. Imper. d. Sci. de St. Petersb. T. V., No. 20.
- BRANDT, J. F.
1841. Recueil de memoires relatifs a l'ordre des Insectes Myriapodes. Extrait du Bull. scientif d. l'Acad. Imper. d. Sci. de St. Petersb. T. V. VI, VII, VIII, et IX. St. Petersbourg et Leipsic.
- KOCH, C. L.
1863. Die Myriapoden. Vol. 1, p. 7-8, tab. III, fig. 8.
- WOOD, H. C.
1865. The Myriapods of North Amer. Art 7, p. 218-219.
- LATZEL, R.
1884. Die Myr. der Ost. Ung. Monarchie. Vol. 2, pp. 40-63.
- MCNEILL, G.
1887. List of Myriapods found in Escambia Co., Fla., with description of twelve new species chiefly from Indiana. Proc. U. S. Nat. Mus., vol. 10, p. 329, pl. xii.
- BOLLMAN, C. H.
1893. The Myr. of North America. pp. 83, 91, 108, 123, 151.
- KORSCHULT, E., AND HEIDER, K.
1899. Textbook of embryology of invertebrates. Translated by M. Bernard, edited by M. F. Woodward. Vol. 3, Myriapods, Ch. 26, p. 218-259, fig. 106-128.
- SINCLAIR, F. G.
1910. Myriapods in Cambr. Nat. Hist., Vol. 5.



FIG. 1



FIG. 2



FIG. 3

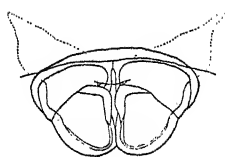
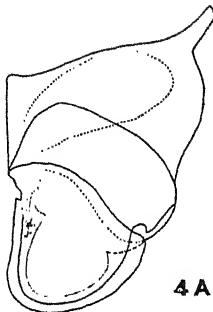
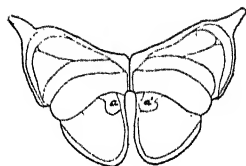


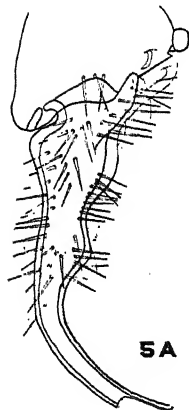
FIG. 4



4 A



4 B



5 A

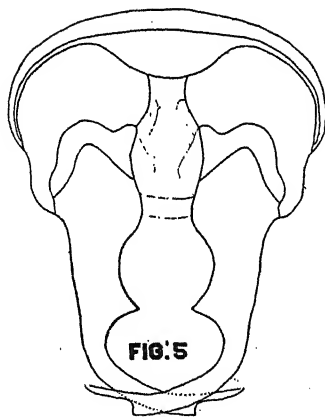
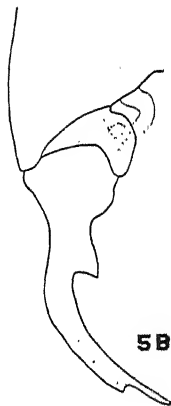


FIG. 5



5 B

Each of the stages in the development of the gonopods was drawn to scale and shows the development as it progressed. The drawings, although necessarily slightly schematic, are in no sense mere diagrams, but are attempts to represent as closely as possible the actual appearance of the objects.

Unless otherwise specified, drawings from ventral side.

- Fig. 1. The single joints or rudiments of the gonopods of a male of the fourth larval stage in place of the eighth pair of legs.
- Fig. 2. Joints of the gonopods shown in the oval disc of an individual of the fifth larval stage.
- Fig. 3. Joints of the gonopods of the sixth larval stage fastened to the oval disc.
- Fig. 4. Joints of the gonopods in place, now free from the sternite, lying in an oval opening in it. Seventh larval stage.
- Fig. 4A. Drawn from mounted gonopods, dissected from the last larval stage.
- Fig. 4B. Detailed drawing of left gonopod.
- Fig. 4B. Gonopods dissected from a freshly killed individual of the last larval stage.
- Fig. 5. Adult gonopods in place in a freshly killed specimen and the oval opening through which the gonopods project.
- Fig. 5A. Right adult gonopod showing the numerous hair-like projections, and transverse hook attached to the coxa.
- Fig. 5B. Dorsal view of right adult gonopod dissected and drawn from a freshly killed individual.

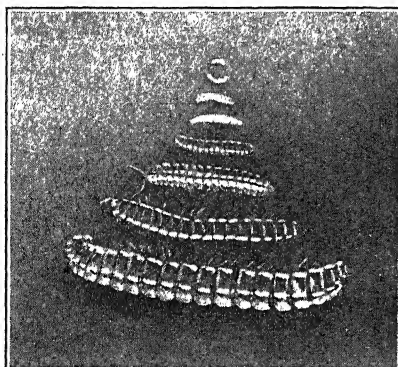


Fig. 6

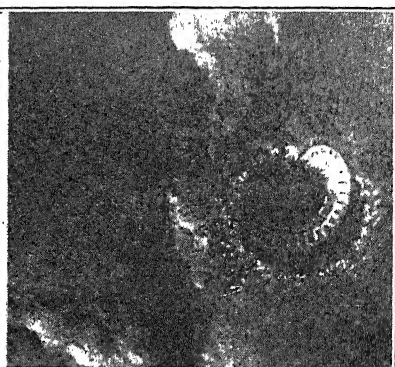


Fig. 7

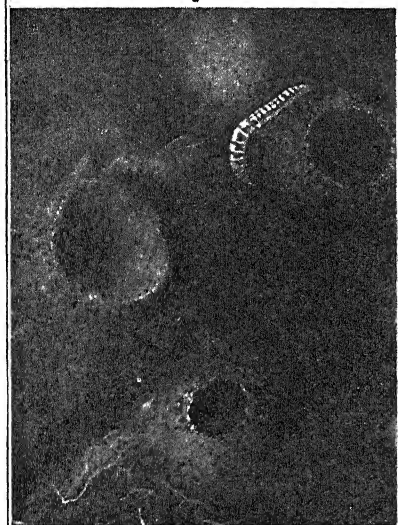


Fig. 8



Fig. 9

- Fig. 6. Photograph of the larval stages and adult of *Euryurus*.
Fig. 7. Photograph of the cast "skin" of a female individual which has moulted from the last larval stage to the adult. The upper part of the cocoon was removed.
Fig. 8. Three cocoons in the process of construction. Two nearly completed and one recently started.
Fig. 9. Photograph of two completed cocoons. The arrow indicates the characteristic chimney-like projection built on top of these.

NEW MEMBERS FOR THE ACADEMY OF SCIENCE

The Executive Committee of the Ohio Academy of Science is very desirous of increasing the sphere of influence of the Academy among the scientifically inclined people of Ohio and, through them, among the residents of the State in general. To this end it is hoped that every member of the Academy will make special efforts to obtain additional members. The Committee feels sure that each member could add several names to the Academy roll. In this connection it should be pointed out that one need not be actively engaged in science to become a member. All that is required is that one be interested in science. The Academy wants and needs the interested layman. A membership limited to professional scientists will be sterile of results in the broader contacts. The laymen can do yeoman service in advancing the ideals of science throughout the State, and there are undoubtedly many of them who would be only too glad to give their support to the Academy if the opportunity were presented to them.

There are some divisions of science in which even those professionally engaged are not well represented in the Academy. This applies especially to the physical sciences.

Each one of us, as members of the Academy, should not feel that his contribution to it or to science in general has been completed until he has increased the roster of those who are affiliated with us. The Academy year is drawing to a close, membership prospects are to be found among the science teachers in the schools, our physicians, our wild-life and out-of-doors enthusiasts. Points that can be mentioned in favor of the Academy are: the Academy has aided in securing legislation for the inauguration of the topographic survey of Ohio, for the better conservation of the bird life of the State and for the establishment of the Ohio Biological survey; the Academy is actively urging forest reserves, game refuges and state parks; one's interest and influence are capitalized by joining the Academy. Each member receives the Proceedings and the six issues of the Ohio Journal of Science upon payment of the annual membership dues which are now only two dollars.

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BIOLOGY OF THE EUROPEAN CORN BORER (*PYRAUSTA NUBILALIS* HÜBN.) AND TWO CLOSELY RELATED SPECIES IN NORTHERN OHIO.

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INTRODUCTION.

The European corn borer, *Pyrausta nubilalis* Hübner, has been referred to as the most important plant pest that has yet been introduced into the United States. It is doubtless one of the greatest potential insect enemies of our corn crop, ranked as the most important crop in the country. Two very closely related American species, the smartweed borer, *Pyrausta ainsliei* Heinrich, and the lotus borer, *Pyrausta penitalis* Grote, although widely distributed over the United States, having been reported from many States east of the Rocky Mountains, have not been found doing commercial damage. Since Heinrich (8)† in 1919 published his paper which gives the description of *P. ainsliei* and the distinguishing characteristics of the three very similar species, Ainslie and Cartwright (1), Ressler (9), Flint and Malloch (7), and Ellis (6) have contributed much to our knowledge of the biology of *P. ainsliei* and *P. penitalis* from the respective localities in which their observations were made. Previous to the advent of *P. nubilalis* into the United States comparatively little attention had been given to these closely related species which are also often found boring in corn to which the larvæ migrate from other hosts. Earlier

*Resigned March 15, 1926.

†Reference is made by number to "Literature cited," p. 86. For complete bibliography of *Pyrausta nubilalis* to January 1, 1925, see Misc. Cir. 46, U. S. Dept. Agric., by J. S. Wade.

papers by Chittenden (4), and others which he refers to, very probably confused *P. ainsliei* with *P. penitalis* when the observations were made upon these insects while infesting the Polygonum group of plants.

The observations on the life history of the three species of *Pyrausta* which are treated in this paper were made at the European Corn Borer Laboratory of the United States Department of Agriculture, Bureau of Entomology, at Sandusky, Ohio, during the four seasons 1922-1925 whereas the observations on the seasonal history were made throughout Northern Ohio, during the same seasons.* No attempt has been made to give a balanced treatment of the three species and the space allotment is not always proportionate to the importance or general interest of the several phases of the biology treated herewith; some phases were less variable and could be summed up more concisely than others, and some were less thoroughly studied.

DISTRIBUTION AND HISTORY OF INFESTATION.

Pyrausta nubilalis was first found in Ohio by Mr. P. A. Howell of the U. S. Bureau of Entomology, on Middle Bass Island in Lake Erie, August 21, 1921. The powers of flight of this insect and the nature of the distribution† (namely, a

*Acknowledgment is made to Mr. D. J. Caffrey, Arlington, Massachusetts, in charge of European Corn Borer Investigational work for the U. S. Department of Agriculture, for an annual plan of work on *P. nubilalis* which was used as a guide in order that the more important investigational work on *P. nubilalis* by the U. S. Bureau of Entomology could be coordinated. In order that all of this work on *P. nubilalis* should be comparable, the methods and cages used at Sandusky were largely the same as those used at the Arlington Laboratory for similar work. I am much indebted to Prof. George A. Dean and Mr. W. R. Walton for their encouragement and suggestions. Special acknowledgment is due Dr. Herbert Osborn of Ohio State University, who had general direction of this work as a research problem for the University and whose interest and helpful criticisms were a source of constant inspiration. Determinations of plants were made by Dr. E. N. Transeau and Prof. J. H. Schaffner, Ohio State University, Columbus, Ohio, to whom thanks are due. Thanks are also due Mr. D. W. Jones, Mr. C. F. W. Muesebeck and Mr. R. T. Webber, of the U. S. Bureau of Entomology, for determining all parasites reared from field collections.

It is a pleasure to acknowledge much valuable assistance from Mr. L. H. Patch, who has recorded many observations and tabulated much data for the writer during the three seasons, 1923-1925, also to the following student assistants at the European Corn Borer Laboratory: Mr. H. S. Peters, during 1924 and 1925; Mr. O. L. Cartwright, during 1924; Mr. L. A. Somers and Mr. N. H. Odell, during 1925. It would be unfair to my wife, Edna Ireland Poos, not to express my appreciation here of her interest in the work and the help which she has given with the manuscript.

†Scouting work to determine distribution in Ohio and Michigan is under the direction of Mr. L. H. Worthley and Mr. E. G. Brewer, of the Bureau of Entomology, U. S. Department of Agriculture, in co-operation with the State Departments of Agriculture of Ohio and Michigan. During 1922-1925 material collected for this purpose was sent to the writer for specific determination.

very sparse infestation and one first found only in the townships which border Lake Erie), seem to indicate that the source of the infestation was Ontario and that adult moths came across the Lake with the aid of favorable winds. U. S. Weather Bureau records at Sandusky, Ohio, show that north winds were prevalent during the latter part of June, 1921, a time when the moths were very actively in flight in Ontario. It is doubtful whether this insect was present in Ohio previous to 1921, and this fact affords a singular opportunity for the study of the increase in intensity of infestation, and seems to justify, at this point a more or less detailed report of the results of such study.

During the season of 1922 infestation counts in 55 fields comprising approximately 175 acres in 11 townships bordering Lake Erie showed only a trace of infestation in 16 of these fields. The maximum percentage of infested stalks in these fields was only a very small fraction of 1, although the number of larvæ that could be collected in a given time was many times greater than it had been in the previous season, according to the records of scouting officials of the U. S. Bureau of Entomology in 1921.

During the season of 1923, field counts for the purpose of determining the percentage of infestation were made in 133 fields comprising approximately 443 acres in 21 townships distributed throughout the area of infestation of the two preceding seasons in Ohio and Michigan, and showed an average of 2.5 larvæ per 100 stalks. The maximum percentage of infested stalks was 17 and the average was found to be 1.83.

During the season of 1924 a phenomenal increase in intensity of infestation was recorded. Field counts to determine the percentage of stalks infested in 241 fields comprising approximately 675 acres in 39 townships distributed throughout the area of infestation of the three previous seasons in Ohio and Michigan showed an average of 9.22 larvæ per 100 stalks. The maximum percentage of infested stalks found was 52. The average percentage of infested stalks for the whole area examined was 5.2, or 2.8 times as great as in 1923. In all field counts to determine the percentage of infestation, the data were taken in such manner that weighted averages could be calculated. The average larval population per stalk was computed and the increase in intensity of infestation is here expressed in actual increase in larval population per 100 stalks, both infested and uninfested, because of the distant and significant

relation which it bears to the amount of damage caused. This method was derived from the one in use at the European Corn Borer Laboratory, Arlington, Mass., and was adapted for use under Ohio conditions.

Up to Jan. 1, 1926, new records of infestation were reported from 315 townships, totalling 8,529 square miles in area, in 31 counties in Ohio, and from 176 townships, totalling 6,232 square miles in area, in 15 counties in Michigan. In 1925, field counts were made in 272 fields, comprising approximately 1,507 acres, in 38 townships in Ohio and in Monroe County, Michigan. The data taken showed an average of 8.63 larvæ per 100 stalks, or a slight decrease compared with counts made over much the same area in 1924. The maximum percentage of infested stalks in 1925 was 63.8 and the percentage of infested stalks in the whole area examined was found to be 5.9, or only 0.89 greater than in 1924. Thus the increase in area and intensity of infestation was very great each year until 1925 when the same rate of increase was not maintained in Ohio. This was probably due to the hot and dry weather conditions which prevailed during the time when the eggs were being deposited.

It was noted in connection with the study of the infestation of *Pyrausta nubilalis* in Ohio that the increase in area was more or less proportional to the increase in intensity of infestation each season, and that optimum conditions for development seemed to be an abundance of available moisture combined with temperature conditions normal or slightly above normal. Little or no damage to the corn crop by this pest has occurred up to the present time (January, 1926) in Ohio and Michigan; but the situation now is such that considerable damage may be expected in many fields in the infested area of Ohio and Michigan during any year which is favorable for the development of the insect, unless crop refuse containing the larvæ is disposed of very effectively in the areas of heaviest infestation.

Larvæ of *Pyrausta ainsliei* and *P. penitalis* have been sent to the writer from many townships in Ohio and Michigan and it is quite likely that both of these species are commonly distributed wherever *Persicaria pennsylvanica* is found abundantly. No lotus* plantations have been examined by the writer which have not contained some infestation by *P. penitalis*. Lotus has been observed in the following localities in Ohio: Buckeye Lake, Oak Harbor, Toledo, and Sandusky.

**Nelumbo lutea* (Willd.) Pers.

EXPERIMENTAL METHODS.

In presenting the data obtained in any biological work a description of the methods used is of the utmost importance. Therefore a brief description of the methods used in obtaining the data which are presented in this paper is given here. Conditions under which some of the observations were made are described in the discussion of these observations.

Material for life-history studies of *Pyrausta nubilalis*, collected in the fall and spring, was kept in wire-screen cages 6 feet by 3 feet by 3 feet (Pl. VI, Fig. 43) under as nearly normal conditions as possible. Pupation in and emergence of *P. nubilalis* from this material were observed to compare very closely with those of *P. nubilalis* in the field.

In obtaining records of the duration of the pupal period small glass tubes (Pl. III, Fig. 27) about $2\frac{1}{2}$ inches long and having an inside diameter of 4 mm. were used. This cage was developed in 1918 by Mr. S. C. Vinal of the Massachusetts Agricultural Experiment Station. As the time for pupation approached, larvæ were placed individually in these tubes, which were labelled with gummed-paper labels for identification. The tubes had a cotton stopper at each end. To facilitate handling and to supply the proper moisture, four to six of these glass tubes were then placed in each of a number of larger glass vials, 100 mm. long by 29 mm. in diameter, which had a round piece of moist blotting paper tightly fitted into the bottom and which were provided with a wire-screen cover for the top to prevent the larvæ from escaping. These larger vials were then placed in wooden racks (Pl. IV, Fig. 28) which were in turn placed in a tightly covered wooden box to exclude the light. Daily examinations were made and as the larvæ pupated, and later as the adults emerged, the duration of pupation was recorded.

No satisfactory method was devised for obtaining, under laboratory conditions, data on the time of pupation that would be fairly comparable to those obtained under natural conditions in the field. If the larvæ are confined in any kind of a cage, their unnatural environment which prevents them from migrating and seeking a new place in which to pupate, apparently greatly delays pupation if it does not entirely prevent it.

Data on mating, oviposition, and longevity of adult moths were obtained from single pairs confined in lantern-globe cages

(Pl. IV, Fig. 30) in the insectary. Each of these cages consisted of a lantern globe, with a 14-mesh screen-wire or mosquito-netting cover, placed upon a 5-inch flower pot filled with moist sand into which a glass vial 74 mm. in length by 14 mm. in diameter was thrust. The stem of the host plant was placed in this vial, which was filled with water each day in order to keep the host plant in good condition for egg deposition. A suitable gummed label was attached to each lantern globe so that the cage could be identified at all times.

Number and duration of larval instars were obtained in small glass vials 50 mm. in length by 10 mm. in diameter, each of which contained a young larva that had just hatched. These vials were placed with the open end tightly fitting into a plaster of Paris block especially prepared for this purpose. This block (Pl. III, Fig. 25) was 16 inches in length, 5 inches high and 4 inches wide and was placed on a wooden base in order to protect it and facilitate handling it. Each block contained 64 holes which were bored into the sides about $\frac{1}{2}$ -inch in depth and into which the open ends of the glass vials fitted tightly in order to prevent the escape of the small larvæ.

The block contained a trough or depression on the upper surface, 13 inches long, 2 inches wide, and three-fourths inch in depth, into which was placed about 4 ounces of water daily in order to supply adequate moisture to the young developing larvæ. At first the young larvæ of *P. nubilalis* were given only fresh tender leaves of corn and those of *P. penitalis* and *P. ainsliei* were given only fresh leaves of smartweed. After the second molt by the larvæ, the pithy portions of these plants were offered. The larvæ were then usually transferred to larger glass vials, 100 mm. in length by 29 mm. in diameter (Pl. IV, Fig. 28) into which a larger amount of food material could be placed. The larvæ were examined daily and fresh food was given when necessary. When the larvæ molted the exuvæ were removed and placed in small vials, 35 mm. in length by 9 mm. in diameter. The head capsules from each individual were kept in separate vials which were numbered to correspond with the larvæ from which they had come. These vials were all kept in a holder (Pl. III, Fig. 26) which was made from a 2-inch block of wood.

For the purpose of obtaining a known number of larvæ in cornstalks under as nearly natural conditions as possible, 50-pound tin lard cans were used. The sections of stalks and the

larvæ were placed in the cans so that the larvæ entered the stalks and did not escape. A hole to provide proper ventilation was cut in the lid of the can (Pl. IV, Fig. 29) over which was soldered a 20-mesh screen-wire cover.

For the migration or recovery trap (Pl. IV, Fig. 31, and Pl. VI, Fig. 43) used to recover larvæ in the plowing and various other experiments, 1-inch by 6-inch boards, usually 16 feet in length were placed on edge so as to form a square or rectangular inclosure. The edges of the board were buried about 1 inch deep in the ground, the soil being tamped down tightly on both sides to prevent the larvæ from going underneath and escaping. On the side near the top of these boards a strip of double-faced corrugated paper, $1\frac{1}{2}$ inches wide, was tacked for the larvæ to crawl into. On top of the 1-inch by 6-inch boards and the corrugated paper strips boards one-half inch thick and 4 inches wide were nailed with the nails driven only partly down so that the traps could be easily examined. In this way the holes in the corrugated paper were kept nearly dark on top, enough space being left for a ray of light to enter and allow the larvæ a place to spin their hibernating webs but not enough space for the larvæ to escape through the upper opening. Mr. H. G. Crawford, Entomological Branch, Ottawa, Canada, originated the idea of using corrugated paper as a migration trap for larvæ of *P. nubilalis*. If a two-way recovery trap was desired the corrugated paper was placed on both sides of the 1-inch by 6-inch board. The efficiency of this trap was tested during the spring of 1925 by placing a kerosene barrier around a 16-foot by 16-foot recovery trap. Out of 416 larvæ placed on the surface of the ground in this trap during a period of three weeks only 10, or 2.4%, escaped. This trap was therefore 97.6% efficient in this experiment in which every precaution was taken to make it a fair test.

Large larvæ of *P. nubilalis*, *P. penitalis*, and *P. ainsliei* bore through cork stoppers and escape from glass vials in this way; they also escape through cotton stoppers unless these are tightly fitted. It was found necessary to make wire covers for the tops of the vials (Pl. IV, Fig. 28) containing large larvæ of which records were being kept and the loss of which could not be tolerated. The full-grown larvæ easily bore through pasteboard and paper boxes. Larvæ of *P. nubilalis* have been observed boring in soft white pine boards.

HOST PLANTS.

Table 1 is a list of host plants of the three species of *Pyrausta* considered in this paper and is based on the species of plants from within which larvæ of one or another of the three species were collected. The number of host plants of *P. nubilalis* under natural field conditions in Ohio has apparently increased in direct proportion to the increase in the intensity of the infestation. The number of shelter plants will probably continue to increase in direct proportion to the increase in the intensity of the infestation but it is doubtful whether the number of food plants will show the same increase. By food plants are meant those upon which a species develops from the egg to the mature larva; all others are considered shelter plants.

TABLE I.

Host Plants* of *Pyrausta* spp. found in Ohio under natural field conditions, 1922-1925.

Pyrausta nubilalis:†

1. Corn (*Zea mays* L.) Sweet, dent, pop, ensilage, and flint.
2. Smartweed, Knotweed (*Persicaria pennsylvanica* (L.) Small).
3. Rough Pigweed (*Amaranthus retroflexus* L.).
4. Roman Ragweed (*Ambrosia elatior* L.).
5. Water-hemp (*Achida tuberculata* Moq.).
6. Cocklebur (*Xanthium pennsylvanicum* L.).
7. Tall Beggar-ticks (*Bidens vulgata* Greene).
8. Barley (*Hordeum vulgare* L.).
9. Panic Grass (*Panicum capillare* L.).
10. Barnyard Grass (*Echinochloa crusgalli* (L.) Beauv.).
11. Wild Lettuce (*Lactuca canadensis* L.).
12. Smartweed (*Persicaria lapathifolia* (L.) S. F. Gray).
13. Giant Ragweed (*Ambrosia trifida* L.).
14. Velvet Leaf (*Abutilon abutilon* (L.) Rusby).
15. Lamb's-quarters (*Chenopodium album* L.).
16. Tumbleweed (*Amaranthus graecizans* L.).

NOTE.—All of the above, except numbers 1 and 2, were probably only shelter plants.

Pyrausta penitalis:

1. Smartweed (*Persicaria pennsylvanica* (L.) Small).
2. Smartweed (*Persicaria lapathifolia* (L.) S. F. Gray).
3. Smartweed (*Persicaria muhlenbergii* (Wats.) Small).
4. American Lotus (*Nelumbo lutea* (Willd.) Pers.).
5. Corn (*Zea mays* L.) Sweet and dent.
6. Rough Pigweed (*Amaranthus retroflexus* L.).
7. Giant Ragweed (*Ambrosia trifida* L.).
8. Wild Lettuce (*Lactuca canadensis* L.).
9. Curled Dock (*Rumex crispus* L.).

NOTE.—All of the above except numbers 1 to 4, inclusive, were probably only shelter plants. Eggs only were found on *Rumex crispus* (L.).

*Nomenclature in this paper is according to "Catalogue of Ohio Vascular Plants," by J. H. Schaffner in Vol. I, Bulletin 2 of Ohio Biological Survey.

†In some instances first records of occurrence were reported by scouting crews and other collectors. The author has personally verified all of the records reported here.

Pyrausta ainsliei:

1. Smartweed (*Persicaria pennsylvanica* (L.) Small).
2. Corn (*Zea mays* L.) Sweet and dent.
3. Rough Pigweed (*Amaranthus retroflexus* L.).
4. Tall Beggar-ticks (*Bidens vulgata* Greene).
5. Lamb's-quarters (*Chenopodium album* L.).
6. Giant Ragweed (*Ambrosia trifida* L.).
7. Cocklebur (*Xanthium* sp.).
8. Roman Ragweed (*Ambrosia elatior* L.).
9. Indian Hemp (*Apocynum cannabinum* L.).

NOTE.—All of the above except *Persicaria* were probably only shelter plants. Eggs only were found on *Apocynum cannabinum* L.

Indications are that *P. nubilalis* has not actually developed to date in plants other than corn with the possible exception of *P. pennsylvanica* (upon which eggs of *P. nubilalis* were found in the field in two instances in 1925), the other hosts mentioned being only shelter plants. Corn is without doubt the preferred host plant of *P. nubilalis*. It has generally been supposed that sweet corn is a preferred host to dent corn or that the latter is more immune to infestation than the former. All data obtained on this point by the writer show that the location of the corn with respect to the source of the infestation, and the stage of the development of the corn either at the time the eggs are being deposited or when the young larvæ are developing, are much more significant factors than the difference in the type of corn. In lantern-globe cages the moths of *P. nubilalis* exhibited little preference, if any, for host plants upon which to deposit their eggs. Several hosts, including corn, dandelion, pigweed, plantain, smartweeds, mustard, beggar-ticks, cocklebur, and burdock, were offered individually for this purpose and no apparent difference in the number of eggs deposited was noted in the case of *P. nubilalis*.

Pyrausta penitalis develops rapidly upon lotus and in the region of Sandusky Bay seems to build up its population on this host. However, the number of individuals that survive the winter in lotus is apparently very small indeed because this plant falls into the water late in the fall in this region, though it may later wash ashore. Very careful search in the remains of this host plant during the spring of 1923, and again during the spring of 1925, revealed no larvæ of this species except in one instance when two larvæ were found within a seed pod which had apparently been washed ashore. Most of the overwintering larvæ of this species were found in smartweed and in corn in this section. No difficulty was experienced in rearing individuals on smartweed which hatched from eggs that had

been deposited on lotus, and vice versa. The mature larvæ, the pupæ, the moths, and the egg clusters were apparently considerably larger, on the average, when they developed on lotus than when they developed on smartweed under natural conditions. In lantern-globe cages, moths of *P. penitalis* seemed to prefer smartweed to other plants which were offered as hosts upon which they might deposit their eggs. Eggs were deposited upon plantain, mustard, catnip, teasel, dandelion, and corn in the cages. None were obtained upon lamb's-quarters. Lotus was not available for a fair comparison in this experiment.

Under natural field conditions *Pyrausta ainsliei* was found to develop only on *Persicaria pennsylvanica*. Eggs of *Pyrausta ainsliei* were collected in one instance in 1925 upon *Apocynum cannabinum*, but in confinement no larvæ could be reared upon this plant. Ellis (6) reports *Apocynum androsaemifolium* L. and eight other species of food plants for *P. ainsliei* in New England, so it is quite evident that the food habits of this species vary greatly in different localities.

Pyrausta ainsliei and *P. penitalis* have often been found to be developing in one plant of *Persicaria pennsylvanica* under natural conditions in the field and sometimes larvæ of *P. nubilalis*, which apparently were migrants, were also found in the same *Persicaria* plant. Larvæ of all three of these species of *Pyrausta* have also been collected in the same cornstalk under natural conditions in the field.

The reaction of newly hatched larvæ of *Pyrausta nubilalis*, *P. penitalis*, and *P. ainsliei* to various plants in confinement was studied. The greater part of this work was done during the season of 1925; all tests, however, carried on previous to this season were repeated with similar results. The host plants which were used in these experiments were placed in glass vials, 100 mm. long and 29 mm. in diameter. Cotton stoppers were used until the larvæ became too large to escape through the wire top covers (Pl. IV, Fig. 28). From 12 to 20 larvæ which had just hatched were placed in each vial upon each host. A minimum of three vials were used for each test; thus a minimum of 36 larvæ were placed upon each host. If feeding occurred the host material was changed as often as necessary in order to keep it in a good palatable condition. *Pyrausta nubilalis* was reared, from egg to mature larva, on 30 of the 63 different plants offered; *P. penitalis* on 17 of the 72 different plants;

and *P. ainsliei* on 8 of the 46 different plants offered to the newly hatched larvæ of this species.

In the case of *P. nubilalis*, rhubarb and Roman ragweed, which are reported as being seriously damaged by this insect in New England, were not accepted as food plants in these experiments.* Potato and beans, which are frequently attacked in New England, were not accepted as hosts in these experiments. Plants which are reported as being occasionally attacked in New England and which were not accepted were as follows: yarrow or milfoil, velvet leaf, tomato, prickly lettuce, lamb's-quarters, and goldenrod. A few plants were accepted for food in these experiments which have not been reported as hosts in New England under natural field conditions. These were black willow, garden lettuce, garden carrot, and lotus. In confinement, the young larvæ of *P. nubilalis* readily accepted corn, dahlia, buckwheat, beet, lotus, cocklebur, sunflower, chrysanthemum, and 2 species of dock and 5 species of smartweed which were offered as food plants. Burdock, gladiolus, the clovers, pigweed, beggar-ticks, lettuce, cowpeas, Roman ragweed, carrot, beans, black willow, and common mallow were not accepted so readily in these experiments, although at least one individual was reared from egg to mature larva upon each of these hosts. It is evident that plants attacked in confinement might never be attacked under natural conditions. It also seems reasonable to expect that plants not attacked in confinement would not suffer any large amount of damage by these insects in the field.

In the case of *P. penitalis*, dahlia, buckwheat, lotus, and all of the species of dock and smartweed which were offered to the young larvæ as food plants in confinement were accepted readily. Burdock, garden lettuce, black willow, alsike clover, red clover, white clover, and common mallow were not accepted readily but at least one larva was reared to maturity upon each of these food plants. All of the other 55 species of plants which were offered to the young larvæ of *P. penitalis* for food were refused.

In confinement young larvæ of *P. ainsliei* developed with about equal rapidity only upon buckwheat, two species of dock, and five species of smartweed which were offered. All of the

*With reference to comparative food habits it should be stated that a two-generation strain of *P. nubilalis* occurs in New England and reference is made only to food habits under field conditions in New England.

other 38 species of plants supplied to the young larvæ of *P. ainsliei* as food were refused.

Larvæ of *P. nubilalis* and *P. penitalis* in the third or fourth instar of their development were transferred from corn and smartweed or lotus, respectively, to plants upon which the newly hatched larvæ of these species did not feed in the experiments previously discussed. In all cases, if the plant to which the older larvæ were transferred contained pithy stems of sufficient size for them to enter, the larvæ were able to continue their development to maturity. This was not true of *P. ainsliei*, as larvæ of this species in the fourth instar were transferred from smartweed to separate vials containing cowpeas, tomato, and red clover and did not complete their development to maturity upon any of these hosts. From the observations made in the case of *P. nubilalis* and *P. penitalis*, it seemed to be necessary for the larvæ of these species to have reached the third instar before the transfer could be successfully effected.

The tests previously discussed are not considered final and complete but, together with field observations on host plants, they indicate that *P. nubilalis* and *P. ainsliei* exhibited much less variation in choice of food plants in Ohio than has been reported in some other localities, whereas *P. penitalis* exhibited a wider choice of food plants, both in the field and in confinement, than has hitherto been reported.

SEASONAL HISTORY.

The three species of *Pyrausta* which are considered in this paper were all observed to overwinter as full-grown larvæ in their respective food or shelter plants. Though there is considerable migrating and boring by the larvæ in the spring before pupation no actual feeding was observed. Small larvæ of *P. penitalis* about which some doubt existed as to whether they were mature were collected from smartweed late in the fall of 1923 to observe if feeding were necessary before pupation during the following spring. No feeding occurred and these individuals pupated normally except that they were smaller than the average.

Only one generation of *P. nubilalis* has been found in Ohio during the seasons 1922-1925 (See Fig. 1). Table 2 gives the comparative records on the phenology of the three species of *Pyrausta* which are considered in this paper. The earliest date that tassels were observed to be broken over by *P. nubilalis*

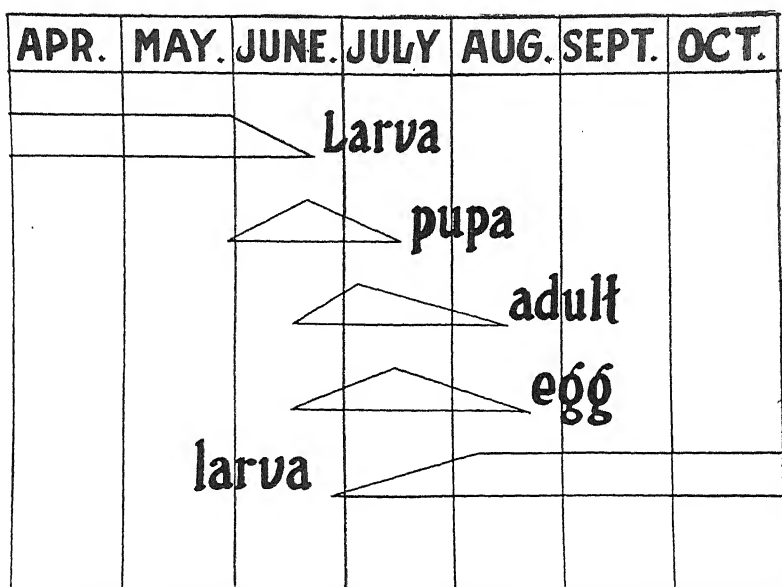


FIGURE 1

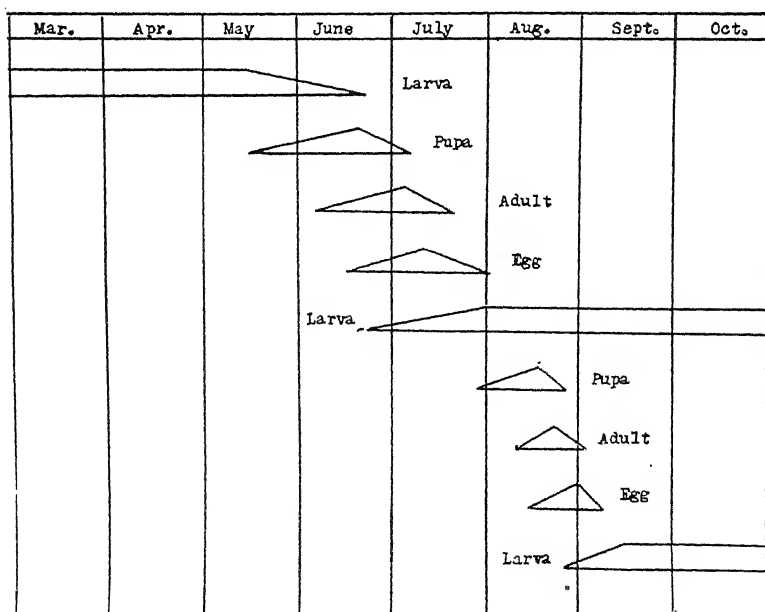


FIGURE 2

was on July 6th; this in 1925, when some larvæ in the fourth instar of their development were observed to be responsible for the work.

P. ainsliei, in the region of Sandusky, Ohio, was found to pass through one complete generation and about 50 per cent

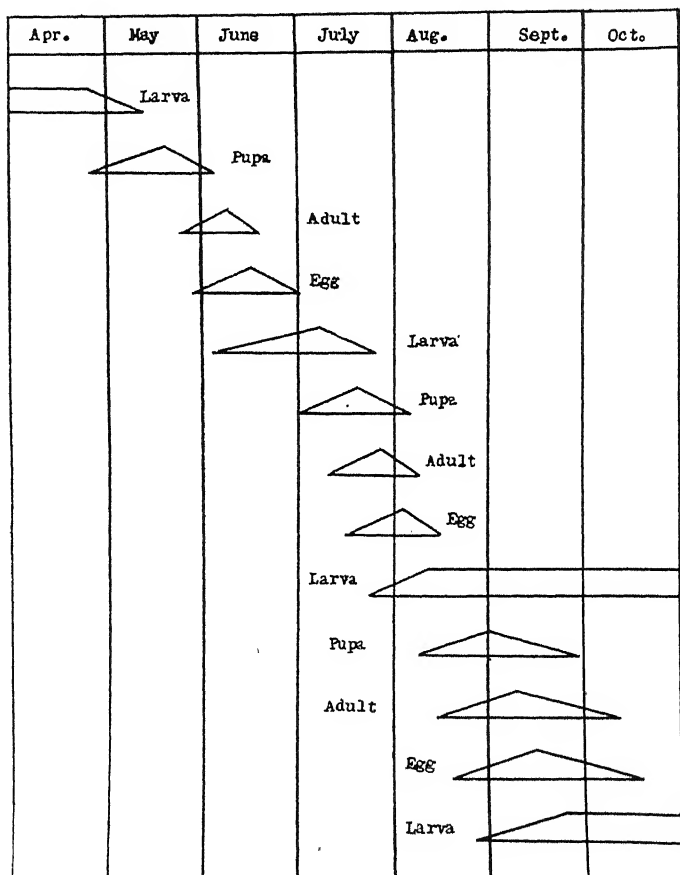


FIGURE 3

of a second generation (See Fig. 2) each season. There was apparently a very marked cessation of pupation by the larvæ of the first generation about the middle of August at which time only about 50 per cent of them had pupated. This also occurred with material which was under observation in the insectary in approximately the same proportion as for individuals in the field.

The observations recorded in this paper on the seasonal history of *P. penitalis* were made almost entirely on lotus which was growing in Sandusky Bay. Three complete generations (See Fig. 3) were observed to develop during the seasons of 1923 and 1925, whereas in 1924 a small percentage of the larvæ of the second generation did not pupate during that season.

TABLE II.

Phenology of *Pyrausta* spp. at Sandusky, Ohio, 1922-1925.

Stage	Generation	Date of first record		Greatest abundance (approximate date)		Last Record	
		In field	In laboratory	In field	In laboratory	In field	In laboratory
Pupa...	<i>P. nubilalis</i>	May 30	June 2	June 26	July 1	July 14	Aug. 12
Adult...	<i>P. nubilalis</i>	June 16	June 9	July 6	July 14	Aug. 13	Aug. 25
Egg....	<i>P. nubilalis</i>	June 16	June 20	July 15	July 20	Aug. 13	Aug. 23
Larva...	<i>P. nubilalis</i>	June 26	June 22	Aug. 5	.....	.....	.....
Pupa...	2nd <i>P. ainsliei</i> ...	May 15	June 4	June 18	June 18	July 4	Aug. 7
Adult...	" " " " " " " "	June 6	June 6	July 4	.....	July 20	July 23
Egg....	1st <i>P. ainsliei</i> ...	June 16	June 15	July 11	.....	Aug. 1	Aug. 9
Larva...	" " " " " " " "	June 21	June 21	July 25	.....	.....	.....
Pupa...	" " " " " " " "	July 30	July 30	Aug. 16	.....	Aug. 25	Aug. 31
Adult...	" " " " " " " "	Aug. 11	Aug. 18	Aug. 25	.....	Sept. 3	Sept. 19
Egg....	2nd <i>P. ainsliei</i> ...	Aug. 23	Aug. 22	Sept. 1	.....	Sept. 3	Sept. 10
Larva...	" " " " " " " "	Aug. 29	Aug. 31	Sept. 8	.....	.....	.....
Pupa...	3rd <i>P. penitalis</i> ...	April 24	May 18	May 25	.....	June 7	June 22
Adult...	" " " " " " " "	May 23	May 23	June 8	.....	June 17	July 10
Egg....	1st <i>P. penitalis</i> ...	May 28	May 29	June 16	.....	July 1	July 12
Larva...	" " " " " " " "	June 3	June 3	July 8	.....	July 26	July 23
Pupa...	1st <i>P. penitalis</i> ...	July 1	July 14	July 20	.....	Aug. 6	Aug. 4
Adult...	" " " " " " " "	July 10	July 19	July 29	.....	Aug. 9	Aug. 23
Egg....	2nd <i>P. penitalis</i> ...	July 16	July 21	Aug. 4	.....	Aug. 15	Aug. 7
Larva...	" " " " " " " "	July 21	July 25	Aug. 8	.....	.....	.....
Pupa...	" " " " " " " "	Aug. 8	July 30	Sept. 1	.....	.....	Sept. 7
Adult...	" " " " " " " "	Aug. 15	Aug. 18	Sept. 10	.....	.....	Sept. 22
Egg....	3rd <i>P. penitalis</i> ...	Aug. 21	Aug. 19	Sept. 15	.....	.....	Sept. 2
Larva...	" " " " " " " "	Aug. 26	Aug. 25	Sept. 20	.....	.....	.....

LIFE-HISTORY STUDIES.

THE PUPA

(Pl. II, Figs. 14-17).

By actual measurement, nine male pupæ of *Pyrausta nubilalis* ranged from 13 to 17 mm. and averaged 15.1 mm. in length and ten female pupæ ranged from 13 to 18 mm. and averaged 16.2 mm. in length. The average length of the nineteen individuals of both sexes was 15.7 mm. Six male pupæ of *P. ainsliei* ranged from 12 to 13.5 mm. and averaged 12.9 mm. in length and nine female pupæ ranged from 13 to 14 mm. and averaged 13.4 mm. in length. The average length of the fifteen individuals of both sexes was 13.2 mm. The average length of sixteen male pupæ of *P. penitalis* was 12.3 mm., ranging from 11 to 15 mm., whereas the average length of fifteen female pupæ was 14.9 mm. and the range was from 14 to 16 mm. The average length of the thirty-one

individuals including both sexes was 13.9 mm. In the field the pupæ of *P. ainsliei* may be easily distinguished from those of *P. nubilalis* and *P. penitalis* by the knob-like projection on the front (See Pl. II, Fig. 16), as determined by Heinrich (8). The pupæ of *P. penitalis* may be easily distinguished from those of *P. ainsliei* and *P. nubilalis* by the very stout and characteristic cremaster, which is broader than long. (See Pl. II, Fig. 17).

Pupation by *P. nubilalis* under natural field conditions in Ohio has been observed to occur only in corn (Pl. III, Fig. 22) within the tunnels which were made by the larvæ. However, in a few instances observed pupation occurred between the stalk and a closely attached leaf, and in this position the individual was usually surrounded by larval frass. Before pupation a circular exit hole is cut by the larva to the surface of the stalk (Pl. III, Fig. 23, at right, and Fig. 24) and this is covered over by a silken opaque partition which closes the outside entrance to the pupal chamber. Quite often the exit hole was observed not cut entirely to the surface of the cornstalk and a thin layer of the epidermis was left (Pl. III, Fig. 23, at left) so that the future moth could easily break through and escape. The outside entrance was usually only 2 or 3 inches from the pupal chamber. Before pupation the larva spins a thin layer of silk around itself which may be called a thin cocoon to which the small spines borne on the last segment of the pupæ are attached. The pupa of *P. nubilalis* has been observed to change completely to the pupal stage within a period of five minutes. The color of the pupæ is yellowish brown for all the species of *Pryausta* which are considered in this paper.

Pupation of *P. ainsliei* under natural field conditions occurred in the stems of *Persicaria pennsylvanica* when it took place in August. In the spring it was observed to occur in shelter plants as well as in the smartweed. Cocoons were not constructed by this species for the protection of the pupæ. The entrance holes to the larval burrows in smartweed were usually from 1 to 4 inches below the pupa and were not closed as in the case of those of *P. nubilalis* in corn. The entrance holes to the tunnel which leads to the pupal chamber of *P. ainsliei* in cornstalks were never observed to be closed. However, the larvæ usually entered the stalk in a position where a closely attached leaf obscured the entrance. The tunnel in smartweed is lightly plugged above and below the pupa with particles of pith which are held together with a network of silk fibers. The pupa lies with head downward in the burrows in smartweed. This was also found to be the prevailing tendency of 138 individuals of this species which pupated in glass tubes and were observed for this purpose, 102 out of 138 pupating with the head downward. Under similar conditions in glass tubes, 162 individuals out of a total of 197 *P. nubilalis* pupated with the head upward. Under the same conditions 29 individuals of *P. penitalis* pupated with the head upward, and 33 pupated with the head downward. An interesting fact in this connection is that 21 out of 24 individuals collected from smartweed in early spring pupated with the head downward, whereas 30 out of 38 individuals collected from lotus later in the season pupated with the head upward, though all were subjected to the same type of cages and methods of handling.

Pupation of *P. penitalis* under natural conditions in the field was usually observed to occur in *Persicaria pennsylvanica* and lotus. The overwintering larvæ were observed to pupate only in the stems of *Persicaria* (Pl. II, Fig. 20) and in shelter plants to which they had migrated. Pupæ of the first generation have been observed in the stems of smartweed and in the petioles of the leaves of lotus near where the leaf is attached to the petiole, and occasionally a pupa of this generation has been found in the rolled-up margins of the leaves of lotus. Seed pods of lotus were not available for pupation by this generation. Pupæ of the second generation have been observed in the seed pods of lotus, in the margins of leaves occasionally, and in the petioles of the leaves. As many as three pupæ have been found in one petiole which contained exit holes and larval tunnels extending down the petiole as far as 10 inches below the leaf. In instances of this kind, the lotus leaves had grown far enough above the water to keep the entrance holes into the petiole above the surface. Pupæ of *P. penitalis* found in smartweed were usually in the stems of the plant, their location being very similar to that of the pupæ of *P. ainsliei* in the same plant as described above, though in some instances the larvæ made exit holes similar to those described for *P. nubilalis* in corn. There was very little cocoon formation (Pl. II, Fig. 20) as in the case of *P. ainsliei*. In the petioles of the leaves and in the seed pods of lotus, the pupæ were well protected by heavy or thick, tough, paper-like cocoons (Pl. II, Figs. 19 and 21) which contrast greatly with the unprotected pupæ of the same species in smartweed and the other shelter plants which the larvæ often select for hibernation and pupation.

A point that may still further emphasize the powers of adaptation of this insect was noted in lotus which had developed without having the leaves float on the surface of the water. In the petioles of such leaves, the exit hole for the future adult even when in the end, was not closed as in the case of individuals which pupated in the petioles of floating leaves. Welch (10) has given an excellent description of the pupal chamber and how it is constructed in the petiole of floating leaves. Later Ainslie and Cartwright (1) recorded additional observations upon this part of the development of the insect in Tennessee. The accurate manner of closing the entrance to the cavity in the petiole in which the pupal chamber is constructed is indeed a clever piece of insect mechanics.

The pupal period of 129 male pupæ of *P. nubilalis* averaged 13.43 days and the pupal period of 137 female pupæ averaged 13.01 days, while the total of 266 individuals of both sexes of *P. nubilalis* had an average pupal period of 13.21 days with a minimum pupal period of 9 days and a maximum of 20 days. The pupal period of 77 male pupæ of *P. ainsliei* averaged 14.0 days and the pupal period of 79 female pupæ averaged 13.59 days while the total of 156 individuals of both sexes of *P. ainsliei* had pupal periods of from 7 to 17 days with an average of 13.8 days. The pupal period of 27 male *P. penitalis* averaged 13.8 days and the pupal period of 68 female pupæ averaged 11.5 days while the total of 95 individuals of both sexes were in the pupal stage from 6 to 31 days and the average was 12.2 days.

THE ADULT.

The adult male and female moths of *Pyrausta nubilalis*, *P. ainsliei*, and *P. penitalis* are shown on Plate I, Figures 1, 2, 4, 5, 7, and 8 and are very intimately related. Distinctive characters for each species are well given by Heinrich (8, p. 178): Superficial adult characters which permit identification of fresh specimens with a fair degree of certainty in the field are as follows: Male moths of *P. nubilalis* have dark, smoky, fuscous wings in combination with the distinct yellow colors of the lighter areas; moths of *P. ainsliei* are usually smaller and do not have the sex scaling of the forewing which is a prominent character in the other two species; moths of *P. penitalis* have a distinctly reddish tinge, the female darker than the male, and beyond the cell in the forewing there is a large conspicuous irregular spot of reddish or grayish scales; this irregular spot is not prominent in the female moth of *P. nubilalis*.

Emergence of the moths of the three species of *Pyrausta* has been observed to take place at all times during the day and night in confinement. The moths of all three species were most active in cages during the early evening or during periods of high atmospheric humidity. They remained quite inactive in cages during periods of comparatively low temperature. In the field only an occasional moth of these species has been observed except in the case of *P. penitalis* in lotus plantations.

The habits of flight of these species were observed to be more or less similar. The males were most often seen and their flights were quite rapid and irregular and were usually only for short distances. They remained close to the ground, where cover was soon sought. Both sexes are accustomed to hiding on the lower surface of the leaves of available plants, and are not very easily disturbed in the daytime under ordinary conditions in the field. Though the moths have not been observed to fly any great distances in the daytime, and their period of greatest activity is at night, it is doubtless true that winds at night are an important factor in the natural distribution of *P. nubilalis*. The prevailing southwest winds in Michigan during the time that the moths are in flight may account for the rapid distribution of *P. nubilalis* over Eastern Michigan. In the season of 1924, at the time the moths were most abundant in the field, two occasions were noted at Sandusky, Ohio, when periods of high atmospheric humidity during the early evening preceded high winds from the north at 10 p.m. and midnight, respectively. This may have been a more or less local condition and of no significance in explaining the unparalleled distance of spread of this insect in Ohio during 1924. Similar weather conditions were not observed to occur at such an opportune time during the other three seasons of observation.

Time of Emergence and Proportion of Sexes.

In Table III is given the results of data obtained on the progress of emergence and the proportion of sexes of moths of *P. nubilalis* during the seasons of 1924 and 1925. The male moths began to emerge first and it may be noted from the data presented in Table III that during

both of the seasons of 1924 and 1925 approximately three-fourths of the individuals which were under observation had emerged before the proportion of males to females became equal. Although the majority of the male moths emerged somewhat earlier than the majority of the female moths, it was observed in these experiments that enough males continued to emerge so that there existed no shortage of males for mating purposes.

TABLE III.

Progress of emergence and proportion of sexes of *Pyrausta nubilalis* at Sandusky, Ohio, 1924-1925.

GENERATION OF 1923					GENERATION OF 1924				
Total Number of Indiv. observed to date	Date	Males	Fe- males	Ratio of males to females	Total Number of Indiv. observed to date	Date	Males	Fe- males	Ratio of males to females
		Percent	Percent				Percent	Percent	
3	7- 1-24	66.6	33.3	2:1	1	6- 9-25	100	0	1:0
230	7-10-24	65.7	34.3	1.92:1	12	6-14-25	91.7	8.3	11:1
308	7-11-24	59.8	40.2	1.49:1	100	6-21-25	85	15	5.7:1
517	7-14-24	54.2	45.8	1.18:1	161	6-23-25	74.6	25.4	2.9:1
613	7-16-24	50.6	49.4	1.02:1	391	6-27-25	65.8	34.2	1.92:1
648	7-17-24	49.7	50.3	.988:1	679	6-30-25	53.6	46.4	1.16:1
683	7-18-24	49.0	51.0	.961:1	1,288	7- 6-25	50.5	49.5	1.02:1
774	7-23-24	48.4	51.6	.938:1	1,366	7- 7-25	49.9	50.1	.996:1
803	7-26-24	47.0	53.0	.887:1	1,474	7-11-25	48.8	51.2	.953:1
828	8-12-24	46.1	53.9	.855:1	1,537	7-15-25	48.5	51.5	.942:1
					1,606	7-30-25	48.2	51.8	.931:1
					1,620	8-14-25	48.3	51.7	.934:1

Longevity.

Observations on longevity of adult moths of the species of *Pyrausta* under observation during the seasons of 1921-1925, inclusive, were obtained in lantern-globe cages. It was observed that 233 male moths of *P. nubilalis* lived from 2 to 42 days and an average of 20.4 days and 125 female moths of *P. nubilalis* lived from 4 to 40 days and an average of 18.9 days. The total of 358 individuals including both sexes of moths lived an average of 19.9 days.

In the case of *P. ainsliei*, 49 male moths lived from 4 to 26 days and averaged 15.7 days and 41 female moths lived from 6 to 24 days and averaged 14.1 days. The total of 90 individuals of both sexes of moths lived an average of 15.0 days.

Seventy-five male moths of *P. penitalis* lived from 5 to 32 days and an average of 14.5 days and 81 female moths lived from 6 to 23 days

and averaged 12.5 days. The total of 156 moths of both sexes under observation for this purpose had an average longevity of 13.5 days.

In these experiments no special food was provided. An abundance of moisture and a suitable host plant were provided in the cages (Pl. IV, Fig. 30). All longevity records included in the foregoing data were taken on mated moths or those which had opportunity to mate. Usually two male moths and one female moth were placed in each cage. In some cases when male moths were not available in sufficient numbers, one individual male was used in two or more cages in order to obtain as many fertile females as possible for oviposition records. This apparently did not adversely effect the length of the life of the individual so used. During July, 1925, 25 unmated male moths of *P. nubilalis* lived from 3 to 25 days and averaged 15.2 days.

Five unmated female moths of *P. penitalis* under observation in September, 1925, lived from 5 to 11 days or an average of 8.2 days while 6 mated female moths under observation at the same time lived from 12 to 17 days and averaged 14 days.

The average longevity of male moths of *P. nubilalis* was 1.5 days greater than that of the female moths; the average longevity of male moths of *P. ainsliei* was 1.6 days greater than that of the female moths; the average longevity of the male moths of *P. penitalis* was two days greater than that of the female moths. Both sexes of moths of *P. penitalis* average 1.5 days and 6.4 days less longevity than both sexes of moths of *P. ainsliei* and *P. nubilalis* respectively.

This result would naturally be expected in view of the fact that *P. nubilalis* has only one generation, that *P. ainsliei* has one generation and a partial second, whereas *P. penitalis* usually has three complete generations annually in the locality where the foregoing longevity records were made.

Copulation.

Copulation by moths of *P. nubilalis* was observed to take place at any time during the day or night. Before copulation the male was observed to approach the female from the rear and with the long axis of his body at right angles to the abdomen of the female he vibrated his wings and antennae very rapidly for a period of from a few minutes to an hour continuously. With genital organs extended, the male moth then threw the tip of the abdomen toward and at right angles to the genital organs of the female moth. When coition was successful the vibration of the wings and antennae was stopped. One male was observed to make 16 unsuccessful thrusts of his abdomen in attempting coition. In copula, the head of the male moth was sometimes at the right side of the female moth and sometimes at the left side; the wings of the female moth were above those of the male or vice versa on the side where the wings came into contact. The tips of the abdomen were directly opposite each other but the heads and thoraces were at right angles, or less than right angles, to each other. The average duration of the copulation period for seven pairs of moths observed in cages was two hours. The moths are polygamous but one mating is apparently sufficient to insure the fertility of the total complement

of eggs. Five male moths of *P. nubilalis* lived from 16 to 41 days or an average of 28.4 days and fertilized from one to four females each or an average of 2.4 females. One hundred and eleven virgin female moths were used in this experiment and kept for fertility records; 70 of them deposited eggs. All of the eggs of 12 of these females were fertile.

Males were observed apparently attempting to mate with females which were engaged in depositing eggs. The males were also observed to attempt mating with a female or male which was already in copula but the observations made showed only one instance where any apparent disturbance was affected.

Oviposition Periods.

The preoviposition period of 119 female moths of *P. nubilalis* ranged from 1 to 14 days with an average of 4.4 days, whereas the oviposition period ranged from 1 to 28 days with an average of 12.8 days and the postoviposition period ranged from 0 to 20 days with an average of 2.5 days. There was an average of 1.9 days, a maximum of 13, and a minimum of 0, in the oviposition periods of these 119 female moths of *P. nubilalis* in which no eggs were laid.

Thirty-nine female moths of *P. ainsliei* had a preoviposition period of from 1 to 9 days with an average of 2.97 days; an oviposition period of from 3 to 16 days, with an average of 9.02 days; a postoviposition period of from 0 to 13 days, with an average of 2.82 days. There was an average of 2.2 days, a maximum of 8 and a minimum of 0, in the oviposition periods of these 39 female moths of *P. ainsliei* in which no eggs were laid.

Eighty female moths of *P. penitalis* had a preoviposition period of from 1 to 5 days with an average of 1.87 days; an oviposition period of from 3 to 21 days, with an average of 9.4 days; a postoviposition period of from 0 to 12 days, with an average of 1.9 days. There was an average of 1.13 days, a maximum of 15 and minimum of 0, in the oviposition periods of these 80 female moths of *P. penitalis* in which no eggs were laid.

It was observed from a small number of female moths which deposited only infertile eggs that the preoviposition period was, on the average, much longer than for moths depositing fertile eggs. The oviposition periods of the same infertile moths were, on the average, much shorter than those of the moths depositing fertile eggs, whereas the postoviposition periods of the same infertile females would average much longer than those of the moths which deposited fertile eggs.

Oviposition Records.

In Table IV, is given in summary form the oviposition records of *P. nubilalis*, *P. ainsliei*, and *P. penitalis* which were obtained during the three seasons of 1923-1925 inclusive. Under natural conditions eggs of *P. nubilalis* could not be readily found in Ohio until 1924 when a total of 731 clusters containing from 2 to 69 eggs each and averaging 15.5 were observed in the field. Only 6 of 89 clusters observed in the field on July 15, 1924, were found on the upper side of the leaf. In 1925 a total of 1,210 clusters containing from 1 to 64 eggs each were observed

TABLE IV.
Oviposition records of *Pyrausta* spp. at Sandusky, Ohio, 1923-1925.

Generation of—	% number of individuals under observation	Total Number of eggs			Total Number of Clusters			Average Number of eggs per cluster			Average Number of eggs per day over oviposition period			Greatest Number of eggs in one day		
		Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
<i>P. nubilalis</i> , 1922.....	25	694	0	321	109	2	24	30.8	3.5	14.0	107	8	40.7	271	17	113.8
<i>P. nubilalis</i> , 1923.....	50	1,075	0	585	88	1	37.14	39.8	2	10.75	67.1	1	40.8	190	2	114.6
<i>P. nubilalis</i> , 1924.....	53	1,100	0	635	61	1	35.75	39.7	5.2	19.62	103.3	2.36	51.54	281	9	138.4
Totals and averages.....	128	956.3	0	654.5	86	1.3	33.9	36.8	3.6	17.5	92.5	3.79	46.4	247	9.3	124.0
<i>P. ainsliei</i> , 1922.....	10	396	12	223.4	37	4	24.2	13.6	3	9.23	49	1.3	26.9	127	6	77.1
<i>P. ainsliei</i> , 1923.....	14	322	0	196.5	42	6	26.4	17.6	4.4	7.99	45.4	8	26	143	43	68.6
<i>P. ainsliei</i> , 1924 (1st).....	7	364	24	191.4	33	2	17.7	16.8	4.6	10.8	115	23	22.6	115	23	66.2
<i>P. ainsliei</i> , 1924.....	2	195	0	97.5	21		10.5	9	1	9	39		39	87		87
<i>P. ainsliei</i> , 1925 (1st).....	8	479	13	254	48	6	25	13	3	10.1	36.8	1.6	23.8	140	10	74.5
Totals and Averages.....	41	351	10.8	212.6	36.2	4.5	23.2	14	3.2	9.36	57	8.5	24.7	122.4	20.5	70.2
<i>P. penitalis</i> , 1922 (3rd).....	2	416	347	381.5	66	28	47	14.8	5.3	8.1	69.4	69.3	69.4	168	137	147.5
<i>P. penitalis</i> , 1923 (1st).....	9	1,921	1,025	1,436	124	34	70.9	40.3	15.5	22.5	225.8	102.6	156.1	867	302	623
<i>P. penitalis</i> , 1923 (3rd).....	10	1,650	47	603.6	75	24	45.5	20.7	1.7	13.2	131.6	29.5	67.1	360	24	196.9
<i>P. penitalis</i> , 1924 (1st).....	12	1,703	660	1,313	105	20	71.3	65.1	12	18.4	226	90.5	131	603	324	474.5
<i>P. penitalis</i> , 1924 (2nd).....	15	1,486	84	729.5	70	8	41.07	25.6	3.3	17.76	194	29	100.6	690	58	366
<i>P. penitalis</i> , 1924 (3rd).....	20	996	407	701.4	77	25	47.65	25	10	15.7	122	40	72.73	271	90	200
<i>P. penitalis</i> , 1925 (2nd).....	6	1,544	676	1,230	86	42	59.5	31	13	21	186	75	132	517	214	330
Totals and Averages.....	80	1,289.4	463.7	890.9	86.1	25.9	52.5	31.8	8.7	17.1	165.1	62.3	95.9	496.6	102.7	327.9

under natural field conditions. The total number of eggs thus observed was 17,216 eggs and the average number of eggs per cluster was 14.22. Twenty-eight, or 2.3 per cent, of the clusters containing 470, or 2.7 per cent, of the total number of eggs were deposited upon the upper surface of the leaves. The remainder of the eggs were, for the most part, deposited upon the lower surface of the leaves, mostly near the middle or base, and comparatively few near the distal third or tip. A few eggs were observed on the stalk, and husk of ears of sweet corn. Fifty clusters of eggs deposited upon sweet corn that was under observation throughout the period of egg deposition in the field in 1925 showed 8 on the husk of the ear and 30 of the remaining 42 on the fifth to eighth leaves inclusive. Fifty-six clusters similarly observed on field corn showed 46 of these clusters on the fifth to tenth leaves inclusive.

In 1925 an attempt was made to determine which sides of the plants, if any, were preferred by the female moths of *P. nubilalis* for depositing their eggs. On July 9th and 10th, 956 clusters were observed for this purpose in a single field of corn. The results did not indicate much preference for any particular side of the plant upon which to deposit the eggs, though 407, or 42 per cent, of the clusters were recorded as being in the northeast quadrant whereas 392, or 41 per cent, of the clusters were in the southwest quadrant.

In 1925 under natural field conditions 9 egg clusters of *P. ainsliei*, observed on the lower side of the leaves of *Persicaria* and *Apocynum*, contained from 5 to 34 eggs each and the average was 16.5.

Under natural field conditions 221 egg clusters of *P. penitalis* collected on lotus during the seasons of 1924 and 1925 contained from 1 to 108 eggs each and a total of 6,002 eggs, or an average of 27.1 eggs per cluster. The clusters of eggs of *P. penitalis* observed on other hosts in the field apparently were not much more than half as large, on the average, as those found on lotus.

In cages an accurate record was kept of the number of eggs deposited by the female moths of the three species upon the glass. In the case of one female moth of *P. nubilalis* 89.3 per cent of the total number of eggs were deposited upon glass. In 1924 and 1925, of the 95 female moths under observation in cages only 10 failed to deposit eggs on the glass. Of the 62,920 eggs observed in cages during these two seasons, 23.4 per cent were deposited upon the glass.

During the seasons of 1924 and 1925, of the 28 female moths of *P. ainsliei* under observation which deposited eggs, only five failed to deposit on the glass. One female moth of *P. ainsliei* deposited 98 per cent her total complement of eggs upon the glass. Of the 6,486 eggs observed in cages during these two seasons, 24.4 per cent, were deposited upon the glass. During the seasons of 1924 and 1925, of the 68 female moths of *P. penitalis* under observation which deposited eggs, only 11 failed to deposit eggs on the glass. Of the 57,040 eggs observed in cages during these two seasons, 21.2 per cent were deposited upon the glass. One female moth of *P. penitalis* deposited 98 per cent of the total number of her eggs upon glass. Thus the female moths of these three species paralleled one another closely in this habit.

Female moths of the three species which deposited no fertile eggs in the oviposition experiments during 1923-1925 numbered 23 out of 249 individuals under observation. These infertile moths deposited a much smaller number of eggs when compared with the general average of each species. The eggs of the infertile female moths were, for the most part, deposited singly or in small clusters of from 1 to 5 or 6 eggs, except in the case of one individual from which none of the 277 eggs observed for that purpose were fertile and which deposited a total of 845 eggs.

In comparing adult fecundity of the three species of *Pyrausta* under consideration the data in Table IV show that the female moths of *P. penitalis* deposited on the average more than four times as many eggs as did those of *P. ainsliei* and over 60 per cent more than did *P. nubilalis*. The data obtained indicate that the female moths of *P. penitalis* of the first and second generations deposit considerably more eggs than those of the third generation which are the first adults to emerge each season, the generations being considered as beginning with the egg.

In lantern-globe cages the female moths of *Pyrausta nubilalis* were observed to assume a position with the head uppermost on the leaf or glass just before depositing eggs. The end of the abdomen was bent downward and the tip of the ovipositor was apparently rubbed over the surface upon which the eggs were to be placed. The female vibrated the ovipositor until the eggs appeared, when they were apparently pushed against the surface and flattened somewhat. The female usually did not change her position while depositing a single cluster of eggs; however, in several instances the female was observed to back downward while depositing a large cluster of eggs, especially if it was three or four times greater in length than in width. The eggs were ordinarily placed in depressions on the surface of the leaf, such as exist along the sides of the midrib, and were placed with the long axis parallel with the veins of the leaf. The hairs of the leaf often extended through the clusters. As many as seventeen eggs were observed to have been deposited within the period of one minute. One female was observed to deposit 130 eggs in one hour. Usually a period of about five minutes was required for depositing the ordinary cluster which contained from 12 to 20 eggs.

THE EGG.

Five eggs of *P. nubilalis* on corn averaged 1.24 mm. in length and 1.12 mm. in width; seven eggs of *P. ainsliei* on smartweed averaged 1.33 mm. in length and 1.23 mm. in width; nine eggs of *P. penitalis* on smartweed averaged 1.05 mm. in length and 0.87 mm. in width.

The eggs of the three species (Pl. II, Figs. 10-13) are difficult to distinguish from one another when deposited upon smartweed. The eggs of *P. ainsliei* are usually flatter and slightly larger than the eggs of either *P. nubilalis* or *P. penitalis*. The clusters contain a smaller average number of eggs than in the case of the other two species (See Table IV). By the time one-half of the incubation period is passed the head capsule of the larva of *P. ainsliei* shows through the transparent

corium of the egg and is light brown or pale tan in color whereas in *P. nubilalis* and *P. penitalis* it is always jet black. The eggs of *P. ainsliei* are deposited in small irregularly shaped masses or in rows and are placed shingle-fashion, each egg overlapping about one-fourth of the adjoining previously deposited egg, and lying at an angle of approximately 15 degrees with the leaf surface.

The eggs of *P. nubilalis* are deposited in irregularly shaped masses and overlap in a shingle-like manner, each egg covering about one-third of the adjoining previously deposited egg and lying at an angle of approximately 30 degrees with the leaf surface. The eggs are white when first deposited and often quite iridescent. Later a crescent-shaped clear space is formed in the center of the egg on its upper surface.

The eggs of *P. penitalis* are deposited in irregularly shaped circular masses and overlap in a shingle-like manner, each covering about three-fourths of the adjoining previously deposited egg and lying at an angle of from 30 to 75 degrees with the leaf surface. The eggs are apparently at first white and on lotus they soon become amber colored. This apparently does not happen when on smartweed or dock. On smartweed, the color of the eggs is very similar to that described for *P. nubilalis*. On lotus, the egg masses are usually more circular and the angle the eggs form with the surface of the leaf upon which they are deposited is about twice as great as when they are placed on smartweed. Under field conditions, the eggs were observed only upon the upper surface of the leaves of lotus and only on the lower surface of leaves of smartweed and dock.

Incubation Period and Viability of Eggs.

Of the 46,353 eggs of *P. nubilalis* observed only 2 per cent failed to hatch. The incubation period for 799 lots of eggs of *P. nubilalis* observed ranged from 4 to 9 days and averaged 5.47 days.

It was also noted that of the 4,350 eggs of *P. ainsliei* observed during the same three seasons, 9 per cent, failed to hatch and the incubation period of 122 lots of eggs observed varied from 5 to 10 days and averaged 7.02 days.

In the case of *P. penitalis* during the same seasons, 1.8 per cent, of the 37,635 eggs observed for this purpose failed to hatch and the incubation period of 301 lots of eggs ranged from 3.3 to 8 days and averaged 5.2 days.

Thus the incubation period of eggs of *P. ainsliei* was about 37 hours longer than for eggs of *P. nubilalis* and about 42 hours longer than for *P. penitalis*. This difference was observed when the eggs were deposited on the same night and kept under the same conditions in the insectary. The eggs of *P. ainsliei* were about 8 per cent less viable than those of *P. nubilalis* and *P. penitalis* under cage conditions. Only 82 or 0.7 per cent of a total of 11,320 eggs of *P. nubilalis* collected in the field in 1924 were observed to be infertile.

The incubation period was determined in confinement by removing the eggs from the lantern-globe cages each morning. A small section of leaf surface about 1 inch square having eggs upon it was cut in order to remove the eggs from the host plant. These sections of leaves

having the eggs upon them were then placed in a 1-ounce salve box containing moist blotting paper upon which the cage number and date had been written for future identification. The eggs were then observed daily and moisture was supplied as needed. Near the end of the incubation period the eggs were usually observed twice daily in order to determine more accurately the duration of this period.

THE LARVA.

(Pl. I, Figs. 3, 6, 9).

Ten larvæ of *P. nubilalis*, apparently full grown ranged from 20 to 28 mm. in length and the average length was 24 mm. The average greatest width of these larvæ was 3.3 mm. Ten larvæ of *P. ainsliei*, apparently full grown ranged from 18 to 24 mm. and averaged 21.5 mm. in length and the average greatest width was 3.0 mm. Five full grown larvæ of *P. penitalis* which had developed in smartweed ranged from 16 to 20 mm. and averaged 18.6 mm. in length and the average greatest width of these individuals was 3.1 mm. Larvæ of *P. penitalis* which develop on lotus are apparently much larger. One very large individual from lotus measured 33 mm. in length by 5 mm. in width.

The larval characters for distinguishing these species from one another have been well given by Heinrich (8). After examining many hundreds of specimens during the seasons 1922-1925 inclusive, the author is of the same opinion as Ellis (6), that Heinrich's use of the anterior epicranial setal group and puncture to separate *nubilalis* from *ainsliei* is the only character that can be used reliably to separate the two species in all larval stages.

The head capsules of the various instars of *P. nubilalis* and *P. ainsliei* were measured with the following average widths given in millimeters:

Number averaged	1st	2nd	3rd	4th	5th	6th
5 <i>P. nubilalis</i>	0.41	0.63	1.00	1.62	2.00	
5 <i>P. nubilalis</i>.....	.41	0.58	0.89	1.38	1.86	2.69
5 <i>P. ainsliei</i>	0.51	0.73	1.02	1.51	2.32*	

It was noted in these measurements that the head capsule of the *P. ainsliei* in the first instar was slightly larger than that of *P. nubilalis* in the same stage of development, though the same proportion is not maintained throughout the other instars. The head capsules of individuals of *P. nubilalis* which molted only five times before pupation were on the average somewhat smaller than those of individuals which molted six times.

Larval Metamorphosis.

A summary of the results of the study of larval metamorphosis during 1924 and 1925 is given in Tables V and VI. The mean temperatures for the various periods during which these larvæ were developing

*Six full-grown individuals were measured. They were not the same individuals from which the head capsules of the other instars were measured, as was the case in all measurements of *P. nubilalis*.

were calculated by the aid of a planimeter and the comparative duration of larval instars shows that the temperature was not the controlling factor in causing the difference in the number of molts. Since all the material that was used in this study was kept in the instrument shelter with the thermograph, the temperature records should be acceptable. In comparing the duration of larval instars of *P. nubilalis* for 1924 and 1925 (See Table VI) it will be noted that the duration of the first three instars compared very favorably during the two seasons but that individuals which molted five times had a fourth instar averaging from 2.12 to 4.26 days shorter in duration than for individuals which molted only four times during their larval stage. Although there are only a comparatively small number of individuals for comparison of the duration of the first four larval instars of *P. ainsliei* and *P. penitalis* with those of *P. nubilalis* the length of each period is quite similar, though of somewhat shorter duration in *P. ainsliei* and *P. penitalis*. Only second-generation individuals of *P. penitalis* were observed each season because they only were available at the time when the other work could be done.

Habits of the Larvæ.

Observations made on the habits of the larvæ of *P. ainsliei* closely parallel those recorded by Ainslie and Cartwright (1) in Tennessee. Young larvæ were always found to feed gregariously during the first and second instars of their development. As many as 18 larvæ in the second instar have been found feeding in one internode in smartweed. When the older larvæ enter the smartweed to feed, the entrance hole (Pl. VI, Fig. 42) was always observed to be on the lower side of the leaning stems at the nodes. As many as ten consecutive nodes of one stem of smartweed have been found thus infested. The larvæ of the first generation were not observed to migrate to other hosts to pupate during the same season. No larvæ of *P. ainsliei* unless full grown were observed in any host other than *persicaria*. Migration to other plants from *Persicaria pennsylvanica* was observed both in the fall and again in the spring.

Observation on the larval habits of *P. penitalis* involve both aquatic and terrestrial studies. The feeding habits of the larvæ on smartweed were observed to differ little from those of *P. ainsliei* on the same plant (Pl. VI, Fig. 39) although the larvæ of *P. penitalis* do not enter the plant early in their development and often have the habit of webbing the leaves together and feeding gregariously under the web. Although both *P. ainsliei* and *P. penitalis* have been observed to injure smartweed considerably, the damage on the whole was slight compared with that often done by *P. penitalis* to the lotus in Sandusky Bay (Pl. V, Fig. 34), where the leaves were found in all conditions, sometimes floating, and sometimes extending 20 to 30 inches above the surface of the water. Often these latter leaves were cupped with the margins higher than the centers. Often the larvæ fed along the margins of the leaves and caused them to roll up and form ideal protection. As many as 38 larvæ were found feeding in this manner on one leaf. A large number of the larvæ, upon reaching the third instar, enter the petioles from the top of the floating leaves; however, many of the larvæ continue to feed and

The tunnelling is not confined entirely within an internode and is also not parallel to the vascular bundles, but the tunnels may run in almost any fashion and weaken the stalk in a most pronounced manner. A preference for the pedicels is often shown by the larvæ, which frequently enter the ears in this way (Pl. V, Fig. 33), boring through all parts of the cob and grain. Not infrequently the injury to the ear (Pl. V, Fig. 32), without the presence of the larvæ which were responsible for it, is difficult if not impossible to distinguish from that of the corn ear worm. During August and September of 1923, 224, or 8.7 per cent, of 2,568 larvæ collected were found in the ears. In 1924, 110, or 5.7 per cent, of 1,937 larvæ collected during August and September were found in the ears.

The full-grown larvæ, especially of *P. nubilalis*, after finishing most of their feeding, seem to possess a restless disposition and usually migrate considerably. Quite frequently the larvæ leave a stalk one or more times only to re-enter it at some other point. Often several stalks are entered by a single larva.

Winter Mortality.

Winter-killing of the larvæ of *P. nubilalis* is not a factor of any great importance in keeping this insect in check. In April, 1924, 1,112 larvæ were observed for this purpose and 69, or 6.2 per cent, were found dead, their death being attributed to winter-killing. During the spring of 1925, a total of 1,660 larvæ were observed and 154, or 9.3 per cent, were found dead.

No definite counts on a large scale were made to determine the percentage of winter mortality of larvæ of *P. penitalis* and *P. ainsliei* in the field. From general observations, however, these two species do not suffer any greater mortality on account of winter-killing than does *P. nubilalis*. During the spring of 1925, of 154 individuals of *P. penitalis* which were observed under natural field conditions only 4, or 2.59 per cent, were found dead, their death being attributed to winter-killing.

Hibernation.

The larvæ of *P. nubilalis* are able to hibernate under unfavorable conditions and, although delayed, a comparatively large percentage are able to transform into adults.

The tendency toward pupation in the soil was greater than was anticipated but it is very doubtful if successful emergence follows such pupation under normal field conditions. Unless crop refuse for pupation were at hand, cultivation and the weathering of the soil would almost certainly preclude successful pupation and adult emergence. Pupation in the soil was tested in a preliminary way in the spring of 1925 by placing a large number of active larvæ among clods in two cages 3 feet by 5 feet which contained the usual recovery traps of corrugated paper and were tightly covered by fine copper-screen wire. The results showed that four individuals emerged from the clods as adults, or 6.8 per cent of the larvæ otherwise unaccounted for.

In the spring of 1925, a suprisingly large number of larvæ of *P. nubilalis* per acre were found in cornstalks and weeds on the surface of the land. The plant remains on an area of 48 square rods distributed throughout seven fields which had from 3 to 31 per cent of their stalks infested by *P. nubilalis* in 1924 contained 110 larvæ, or an average of 366 per acre. These fields were examined between April 24 and May 29 and contained from 106 to 768 larvæ per acre each, according to these data.

OBSERVATIONS ON CONTROL FACTORS.

Trap Crops.

The possibility of using early sweet corn as a trap crop to aid in the control of *P. nubilalis* was a matter of special investigation in 1924. Accurate dates of planting were obtained upon fields of sweet corn and dent corn which were located near together in 19 instances in 11 townships in northern Ohio and Monroe County Michigan. Field counts to determine the value of trap crops were made in these fields, and under the existing status of the infestation by *P. nubilalis* the results obtained were negative. In 1925, 14 similar comparative examinations were made in seven townships in the same area as during the previous year, and the results obtained were similar in that they indicated that early sweet corn did not function as a trap crop under the conditions of the existing sparse infestation.

The comparative infestation by *P. nubilalis* of sweet corn and dent corn was observed each season during 1922 to 1925 and during 1922 sweet corn seemed to be slightly more infested than dent corn. The results obtained during 1923 to 1925 are tabulated in Table VII which shows that during 1923 the larval population was much greater in the fields of dent corn than in those of sweet corn examined. This was because the maximum infestation for the season was found in some large fields of dent corn, late in the season when it was too late to make counts in proportionate areas of lighter infestation. By giving weighted averages of these acreages which included these fields, the figures given above were obtained. The difference in larval population is apparently due to the comparative ability of the larvæ to establish themselves on sweet corn and dent corn rather than to preference of the sweet corn by the moths as was shown by other observations which lack of space prevents recording here.

Observations on the comparative infestation by *P. nubilalis* in relation to the time of planting both sweet and dent corn were started by the writer in 1923 and continued during 1924 and 1925. Accurate dates of planting were obtained in all instances. A total of 137 fields of sweet corn and 138 fields of dent corn were examined for this purpose during the three seasons. A summary of these examinations each season indicated that all corn planted after June 1 showed much less infestation than earlier plantings under the existing status of the sparse infestation. Caffrey (3, p. 105) has published the detailed summary of examinations made in 1924.

TABLE VII.

Comparative infestation of sweet corn and dent corn by *P. nubilalis*.

Year	Number of Fields		Percent of Stalks Infested		Average Number of Larvæ per Infested Stalk		Number of larvæ per 100 Stalks. (inf. and uninf.)	
	Sweet	Dent	Sweet	Dent	Sweet	Dent	Sweet	Dent
1923	73	59	0.3	2.4	1.6	1.4	0.5	3.4
1924	102	139	6.3	4.9	2.5	1.4	16.0	7.2
1925	86	137	8.4	6.4	1.9	1.2	16.7	7.9

Experimental Plantings.

During 1922 and 1923 a very sparse infestation by *P. nubilalis* was obtained in the experimental plantings at Sandusky, Ohio. During 1924 and 1925 plantings were continued in cooperation with the Department of Agronomy, Ohio Agricultural Experiment Station, and the varieties were selected in accordance with the recommendations from that Department after considering the needs from the standpoint of the corn borer problem. Plantings of all plots and harvesting of the dent corn in order to obtain accurate data on yields were personally directed by Mr. L. E. Thatcher and Mr. C. E. Dike. Table VIII gives the summary of the infestation in these plantings. It is recognized that the sparse infestation obtained makes these data of doubtful value in predicting what would occur under conditions of a heavy infestation by *P. nubilalis*. The results obtained indicate that the early planted and more

rapidly developing varieties are most subject to infestation if equidistant from the source of the infestation. No tendency of any importance toward immunity has been observed for any variety yet planted for this purpose, and the maximum infest-

TABLE VIII.

Percentage of stalks infested by *P. nubilalis* in experimental plantings at Sandusky, Ohio, 1924-1925.

Variety*	DATES OF PLANTING												Average† for Variety	
	5-1	4-27	5-9	5-7	5-19	5-18	5-28	5-28	6-10	6-8	6-20	6-18		
	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925	1924	1925
Golden Bantam...	4.36	3.04	2.23	4.96	0.70	4.99	0.93	10.00	0	0.77	0	0	1.95	3.99
Stowell's Evergreen.....	1.95	3.22	0.40	1.11	0	1.40	0.30	2.69	0	0.23	0	0	0.52	1.17
Country Gentleman.....	0		0.48		0		0		0.30		0		0.42	
Red Evergreen...		4.35		2.80		2.30		5.51		0.12		0		2.5
Leaming.....			1.92	1.62	1.02	1.31	4.11	2.53	0.19	0.47	0	0	1.64	1.18
Burr-Leaming....			4.66	1.34	5.71	0.94	3.07	1.60	0.40	1.02	0	0	2.53	1.00
Clarage.....			3.55	2.56	1.42	3.23	2.09	3.63	2.25	0.32	0.59	0	1.94	1.93
Golden Glow....				4.79		3.27		4.11		1.12		0		2.64
Low Ear.....				5.45		5.17		6.34		0.65		0.45		3.62
Van Wye's.....				2.24		4.20		3.95		0.11		0		2.13
Stone's Calico....			4.94		5.13		5.57		2.94		0.19		3.90	
Silver King.....			6.19		9.20		4.54		1.33		0		4.06	
Reid's Yellow Dent.....			1.45		4.42		1.77		1.64		0.20		1.94	
Low % Grain Ave. (Clarage)..			3.63		3.27		1.98		1.24		0		1.95	
Northwestern Dent.....			4.81		0		3.16		2.56		0		2.11	
Ivory King,			1.17		2.27		0		0.52		0		0.73	
Averages†.....	2.41	3.91	3.53	3.06	3.63	3.04	2.86	4.68	1.27	0.54	0.12	0.05	2.17	2.31

*All varieties were planted in triplicate plots each one-fortieth acre in area on each date in 1925.

During 1924 all varieties except Burr-Leaming, Ivory King, and Northwestern Dent were planted in duplicate on each date.

†Only weighted averages are given.

ation has been found in corn which was planted at about the date for obtaining the optimum yield, or in earlier plantings. Reference to yield is made to dent corn only. Special observations in the experimental plantings during 1925 indicated that corn planted May 28 developed more rapidly than that planted earlier and thus was taller and in a more thrifty condition during the time most of the moths were in flight.

Cultural Methods.

The effectiveness of disking corn stubble fields as a control measure for *P. nubilalis*, was tested on a small area of stubble during 1924, and again during 1925 and in each instance was found to be an unsatisfactory practice.

Previous to 1923 material of *P. nubilalis* was not abundant enough for plowing experiments in Ohio. Preliminary experiments were started in the fall of that year with artificially infested material. These experiments, together with hand burials of artificially infested stalks containing 750 larvæ, indicated that most of the larvæ which were plowed under or buried before November 1 migrated to the surface during the fall and that the remainder came to the surface during the following spring, as did practically all of those which were plowed under or buried in November. From 8 to 72 per cent of the larvæ were recovered in the traps; the remainder either escaped the traps, were destroyed by birds, moles, mice, ants, beetles, and other predators or died and disintegrated in the soil where no trace was left of them. All plowing referred to in this paper was done to a depth of approximately 6 inches with a 14-inch walking plow which was pulled by two horses.

In the spring of 1924 a similar series of plowings were made. These experiments were closed on June 10 and showed that less than 8 per cent of the larvæ remained in the stalks under the surface, whereas 33 per cent were recovered in the traps. In the spring of 1924, 1,250 larvæ were buried in artificially infested cornstalks in two different types of soil at 10 day intervals from April 12 to May 31. These results obtained were extremely variable and only indicated the need for further work under more natural conditions.

During the fall of 1924, an area 16 feet by 16 feet, containing approximately 100 larvæ (the exact number was recorded in each instance) in 12-inch corn stubble was plowed under weekly from September 16 to December 5. These larvæ were allowed to enter the standing stubble via nail holes and were well established before the plowings were made. No larvæ were recovered in the fall from the last two plowings in this series whereas as high as 51 per cent were recovered in some of the traps around the areas which were plowed under earlier. In the spring of 1925, however, the reverse was true and from 4 to 12 percent of the total number of the larvae plowed under in

this series in the fall before November 1 were recovered whereas as high as 51 per cent were recovered from the areas which were plowed under after November 7. Of a total of 1,110 larvæ plowed under in the fall, 279, or 25 per cent, were recovered in the fall and 241, or 22 per cent, were recovered from these same areas during the following spring. These experiments were closed on June 9 and 10, 1925, when all stubble was dug up and examined thoroughly. A total of 18 living larvæ, 2 living pupa, and two dead larvæ were found. Most of this material was found in stubble on or near the surface which was there because of settling of the soil or its washing by rains.

From March 24 to May 18, 1925, similar experiments were continued at weekly intervals when 12 more areas containing 1,155 larvæ (after subtracting 9.2 per cent which was the percentage of winter mortality determined) were plowed under. From 19 to 55 per cent of the larvæ were recovered in the traps around the various areas and the total recovery in traps was 38 per cent. When these experiments were closed, on June 10-12, a total of 45 living and 6 dead individuals were accounted for in the stubble which was carefully examined. In addition to the foregoing 1,500 naturally infested, especially selected stalks containing one larva each were plowed under, 500 each on April 13, 27, and May 11, respectively. From 21 to 38 per cent of the larvæ were recovered in the traps and a total of 22.8 per cent. These experiments were closed June 12 and 12 living and 5 dead individuals were found in the stalks. From September 19 to May 18 a total of 3,765 larvæ were plowed under and 1,403 or 37.3 per cent, were recovered in traps. From the data obtained in these experiments it would seem that plowing could not be recommended as a satisfactory control measure for this insect. Crawford (5) has found in Ontario under conditions of serious infestation by *P. nubilalis* that clean plowing is an effective control. Opportunity to test this measure under similar conditions in Ohio has not yet presented itself and it is to be hoped that if such conditions should arise, clean plowing will result in as effective a control in Ohio as it has been found to be in Ontario.

In connection with plowing experiments tests were made in order to compare naturally infested material with that which was artificially infested, and it was found that approximately the same percentage of larvæ were ultimately recovered in the traps although most of the larvæ in the artificially infested

material if buried within 24 hours after entering the stalks had a tendency to come to the surface somewhat earlier than those in naturally infested stalks. In connection with the plowing experiments some larvæ of *P. penitalis* were plowed under in smartweed and they exhibited the same habits as did *P. nubilalis* in coming to the surface both in the fall and in the spring.

ENEMIES.

In Ohio, *P. nubilalis* is rarely attacked by native parasites. A few specimens of each species as listed in Table IX have been reared from field collections. A few specimens of *Microbracon gelechiæ* Ashm. were reared from material collected in Erie and Lucas Counties, both in 1924 and 1925. *Trichogramma minutum* Riley was reared from eggs of *P. nubilalis* collected in Erie and Lucas Counties in 1925. In 1923, 6 out of 49 larvæ collected upon one occasion were parasitized by a tachinid. Unfortunately this material was destroyed before a specific determination was obtained.

Table IX gives a list of ten species of parasites which were reared from field collections of *P. penitalis* during the seasons of 1922-1925. No additional species were added to this list during 1925 although a large number of parasites were collected. This was likewise true of collections of *P. ainsliei*, from which four species of primary parasites, as listed in Table IX were reared from field collections. In addition to these a number of specimens of *Dibrachys boucheanus* Riley and of a species of *Pteromalidæ* were reared as secondary parasites from dipterous pupæ (probably *Panzeria penitalis* Coq.) which had developed upon larvæ of *P. ainsliei*. *Rogas rileyi* Cress. and *Exorista pyste* Walk. were reared from field collections of *P. penitalis* or *P. ainsliei* in 1922. The exact host of these parasites could not be determined since the head capsules of the larvæ upon which these parasites had developed were accidentally lost in the wind when this material was collected.

Parasites undoubtedly are an important factor in controlling the abundance of *P. ainsliei* and *P. penitalis* in northern Ohio. *Microbracon caulicola* Gahan and *Panzeria penitalis* Coq. were by far the most numerous of the parasites reared from field collections. *Apanteles harti* Vier. was found to be of some importance as a parasite of *P. penitalis* on lotus. This parasite was never reared from *P. penitalis* on other host plants. No egg parasites of *P. ainsliei* and *P. penitalis* were reared. All of

the primary parasites of *P. ainsliei* and *P. penitalis* referred to above were strictly larval parasites with the exception of *Labrorychus prismaticus* Nort., which emerged from pupæ of *P. penitalis*.

Some collections of *P. ainsliei* and *P. penitalis* from smartweed late in the fall, or in the spring before these species pupated, yielded as high as 85 per cent of parasitized larvæ and not uncommonly as many as 50 per cent of the larvæ were thus attacked.

TABLE IX.

List of parasites reared from field collections of *Pyrausta* spp. in northern Ohio, 1922-1925.

Pyrausta nubilalis:

1. *Microbracon gelechiæ* (Ashm.).
2. *Lixophaga variabilis* Coq.
3. *Trichogramma minutum* Riley.

Pyrausta penitalis:

1. *Microbracon caulicola* Gahan.
2. *Meteorus loxostegei* Vier.
3. *Microgaster epagoges* Gahan.
4. *Apanteles harti* Vier.
5. *Bassus agilis* Cress.
6. *Labrorychus prismaticus* (Nort.).
7. *Microgaster* sp.
8. *Meteorus* sp.
9. *Panzeria penitalis* Coq.
10. *Lixophaga variabilis* Coq.

Pyrausta ainsliei:

1. *Microbracon caulicola* Gahan.
2. *Microbracon epagoges* Gahan.
3. *Bassus agilis* Cress.
4. *Panzeria penitalis* Coq.
5. *Dibrachys boucheanus* Ratz. (Secondary on dipterous pupa).
6. *Pteromalid*. (Secondary on dipterous pupa).
7. *Rogas rileyi* Cress.? (See page 82).
8. *Exortista pyste* Walk.? (See page 82).

No predators of *P. ainsliei* and *P. penitalis* were actually observed though some species were strongly suspected of attacking eggs and larvæ of these two insects. The petioles of floating leaves of lotus at the point where the larvæ or pupæ of *P. penitalis* had been located were often observed to be torn open as described by Ainslie and Cartwright (1, p. 12-13). The depredator which was responsible for this work which occurred at irregular intervals was not observed while actively engaged in destroying *P. penitalis*, a large number of which were destroyed at certain times.

In a few instances larvæ of Coccinellidæ and Chrysopidæ were observed to feed upon larvæ of *P. nubilalis*. All attempts

to rear these predators to adult were unsuccessful. The adults of some of the coccinellids were also strongly suspected of feeding upon eggs of *P. nubilalis* under natural field conditions in a few instances, although this was also not actually observed to occur. In the spring of 1924, in connection with plowing experiments, some larvæ of Elateridæ, determined by Mr. J. A. Hyslop as species of *Limonius* and *Melanotus*, were observed in a few instances to be attacking and killing larvæ of *P. nubilalis* in cornstalks under the surface of the ground. At the request of Mr. Hyslop an attempt to rear these wireworms to adult was made in order to secure more specific determination. No adults have emerged to date (January, 1926). In 1-ounce tin salve-box cages, when the larvæ of these wireworms were given a choice of a freshly sprouted grain of corn and a living larva of *P. nubilalis*, about 35 per cent seemed to attack and kill the larva of *P. nubilalis* in preference to feeding on the corn. It is not the intention to imply that wireworms will ever become a factor in the control of *P. nubilalis*.

The studies which are reported in this paper indicate that the affinities of *P. nubilalis*, *P. penitalis*, and *P. ainsliei* are close. Apparently these species are by far more closely related to one another than to any others of the same genus. *P. nubilalis* was first described in 1796, and what is generally accepted as one and the same species, though it has widely different habits, has been reported from many countries in the eastern half of the northern hemisphere varying in latitude from 13 to 58 degrees. *P. penitalis* was first described in 1876 and *P. ainsliei*, though it is now known to have been confused in the earlier records with *P. penitalis*, was first described in 1919. Both of these species, apparently, have been reported only from the eastern part of the United States. The aquatic adaptations of *P. penitalis* indicate that it may be of the most recent origin. The affinities and origins of these species are suggested only in the hope of attracting interest in further study along this line. The possible economic value of the close affinity of these species should not be overlooked in considering the enemies of *P. ainsliei* and *P. penitalis* as aids in the control of *P. nubilalis*. Thus far only one parasite of *P. penitalis* has been reared from field collections of *P. nubilalis* in Ohio. It should be stated, however, that little time for this work was available. It is greatly to be hoped that, as *P. nubilalis* becomes more abundant, the parasites of *P. ainsliei* and *P. penitalis* will attack it in greater proportions than at present.

SUMMARY.

1. *Pyrausta nubilalis*, the European corn borer, was first discovered in Ohio and Michigan in 1921 and up to January 1, 1926, infestation had been reported from 315 townships totalling 8,529 square miles in area in 31 counties in Ohio and 176 townships totalling 6,232 square miles in area in 15 counties in Michigan. The importance of our corn crop and the rapid increase in infestation by this insect, both in area and in intensity, in this section and its well-known capacity for causing severe losses in Ontario make this species one of the greatest potential insect enemies yet introduced into the United States.

2. The two nearest related species, *P. ainsliei*, the smartweed borer, and *P. penitalis*, the lotus borer, have not been found to be of economic importance, but because of their similarity in appearance in each of the stages they are often mistaken for one another as well as for *P. nubilalis*.

3. In Ohio and Michigan, *P. nubilalis* preferred corn as a host plant, *P. ainsliei* preferred smartweed, and *P. penitalis* preferred lotus and smartweed. In confinement *P. nubilalis* was reared from egg to mature larva upon 30 of 63 species of host plants offered, *P. penitalis* upon 17 of 72 species of plants offered, and *P. ainsliei* upon 8 of 46 species offered. All three species migrated considerably during their larval stage and were often found in many plants upon which the young larva did not develop. This caused confusion in the identity of the three species.

4. These species overwintered as full-grown larvæ in their respective food and shelter plants. *P. nubilalis* has been found to pass through only one generation each year at Sandusky, Ohio, whereas *P. ainsliei* passed through one generation and about 50 per cent of a second generation each year, and *P. penitalis* normally passed through three complete generations when feeding upon lotus.

5. Detailed life-history studies indicated no distinct variations of importance in the habits of the three species except that the average number of eggs per female moth in cages was 212 for *P. ainsliei*; 554 for *P. nubilalis*; and 890 for *P. penitalis*. The viability of the eggs under observation for that purpose varied from 90 to 98 per cent. The larvæ normally molted four or five times and the number and duration of instars of the three species compared closely.

6. Winter mortality was not an important factor in the control of these species. Mortality of larvæ of *P. nubilalis* was very much greater during the early instars of their development. A large percentage of the young larvæ failed to complete their development.

7. Experimental plantings of several varieties of corn during three seasons indicated, under the existing status of light infestation, no appreciable varietal immunity to *P. nubilalis*; also, that corn planted on the optimum (or earlier) dates of planting contained more infestation by *P. nubilalis* on the average than corn planted after June 1st at Sandusky, Ohio.

8. Preliminary experiments on disking and plowing as aids to the control of *P. nubilalis* indicated that these methods could not be relied upon as a complete control.

9. Native parasites were an important factor in the control of *P. ainsliei* and *P. penitalis* but have seldom been observed to attack *P. nubilalis*. The value of the enemies of *P. ainsliei* and *P. penitalis* as possible aids in the control of *P. nubilalis*, however, should not be underestimated.

LITERATURE CITED.

- (1) AINSLIE, G. G., AND CARTWRIGHT, W. B. 1921. Biology of the Smartweed Borer, *Pyrausta ainsliei* Heinrich. In Jour. Agr. Research, v. 20, pp. 837-844.
- (2) AINSLIE, G. G., AND CARTWRIGHT, W. B. 1922. Biology of the Lotus Borer (*Pyrausta penitalis* Grote). In U. S. Dept. Agr. Bul. 1076; 14 pp., 4 pls.
- (3) CAFFREY, D. J. 1925. Status of the European Corn Borer in the United States in 1924. In Jour. Econ. Ent., v. 18, pp. 98-109.
- (4) CHITTENDEN, F. H. 1918. The Lotus Borer (*Pyrausta penitalis* Grote). In Jour. Econ. Ent., v. 11, pp. 453-457, 1 pl.
- (5) CRAWFORD, H. G. 1924. Ploughing As a Factor in Controlling the European Corn Borer (*Pyrausta nubilalis* Hubner) in Ontario, Canada. In Jour. Econ. Ent., v. 17, pp. 132-141.
- (6) ELLIS, WILLIAM O. 1925. Some Lepidopterous Larvæ Resembling the European Corn Borer. In Jour. Agr. Research, v. 30, pp. 777-792, 2 pls.
- (7) FLINT, W. P., AND MALLOCH, J. R. 1920. The European Corn Borer and Some Similar Native Insects. In Bul. Ill. Div. Nat. Hist. Survey, v. 13, pp. 287-305, 44 figs.
- (8) HEINRICH, C. 1919. Note on the European Corn Borer (*Pyrausta nubilalis* Hubner) and Its Nearest American Allies, with Description of Larvæ, Pupæ, and One New Species. In Jour. Agr. Research, v. 18, pp. 171-178, pls. 7-11.
- (9) RESSLER, I. L. 1921. Life History of *Pyrausta ainsliei* Heinr. at Ames, Iowa, During the Season of 1920. In Jour. Econ. Ent., v. 14, pp. 277-280, 1 fig.
- (10) WELCH, PAUL S. 1919. The Aquatic Adaptations of *Pyrausta penitalis* Grt. (Lepidoptera). In Annals Ent. Soc. Amer., v. 12, pp. 213-226.

EXPLANATION OF PLATES.

PLATE I.

- Fig. 1. Adult female of *Pyrausta nubilalis*. About 2X.
Fig. 2. Adult male of *Pyrausta nubilalis*. About 2X.
Fig. 3. Full-grown larva of *Pyrausta nubilalis*. About 2X.
Fig. 4. Adult female of *Pyrausta ainsliei*. About 2X.
Fig. 5. Adult male of *Pyrausta ainsliei*. About 2X.
Fig. 6. Full-grown larva of *Pyrausta ainsliei*. About 2X.
Fig. 7. Adult female of *Pyrausta penitalis*. About 2X.
Fig. 8. Adult male of *Pyrausta penitalis*. About 2X.
Fig. 9. Full-grown larva of *Pyrausta penitalis*. About 2X.

PLATE II.

- Fig. 10. Average sized egg cluster of *Pyrausta nubilalis*, on corn. About 2X.
Fig. 11. Egg cluster of *Pyrausta nubilalis* about 36 hours before hatching. About 2X.
Fig. 12. Egg cluster of *Pyrausta penitalis*, on lotus. About 2X.
Fig. 13. Two egg clusters of *Pyrausta ainsliei*, on *Persicaria pennsylvanica*. About 2X.
Fig. 14. Two pupæ of *Pyrausta nubilalis*. About 2X.
Fig. 15. Lateral view of pupa of *Pyrausta ainsliei*. About 2X.
Fig. 16. Ventro-lateral view of pupa of *Pyrausta ainsliei*. About 2X.
Fig. 17. Dorsal view of pupa of *Pyrausta penitalis*. About 2X.
Fig. 18. Larvæ of *Pyrausta nubilalis* just hatching out. About 2X.
Fig. 19. Pupa of *Pyrausta penitalis* in lotus petiole with cocoon removed which is shown in Figure 21. About 2X.
Fig. 20. Pupa of *Pyrausta penitalis* in smartweed showing absence of cocoon formation. About 2X.
Fig. 21. Pupa of *Pyrausta penitalis* in lotus showing cocoon formation and cap used at upper end of petiole of floating leaves in order to exclude the water. About 2X.

PLATE III.

- Fig. 22. Pupæ of *Pyrausta nubilalis* in situ in pupal chamber in cornstalk, about natural size.
Fig. 23. External appearance of exit from pupal chamber of *Pyrausta nubilalis* in cornstalks. The exit at the right has been closed by the larva by spinning a web before pupating; the exit at the left was left closed by a thin section of epidermis. 2X.
Fig. 24. Internal appearance of exit hole shown in Figure 23 on the right. 2X.
Fig. 25. Cage used for obtaining number and duration of larval instars.
Fig. 26. Method of keeping head capsules of the larvæ observed for number of larval instars.
Fig. 27. Glass tubes in which duration of pupation was recorded.

PLATE IV.

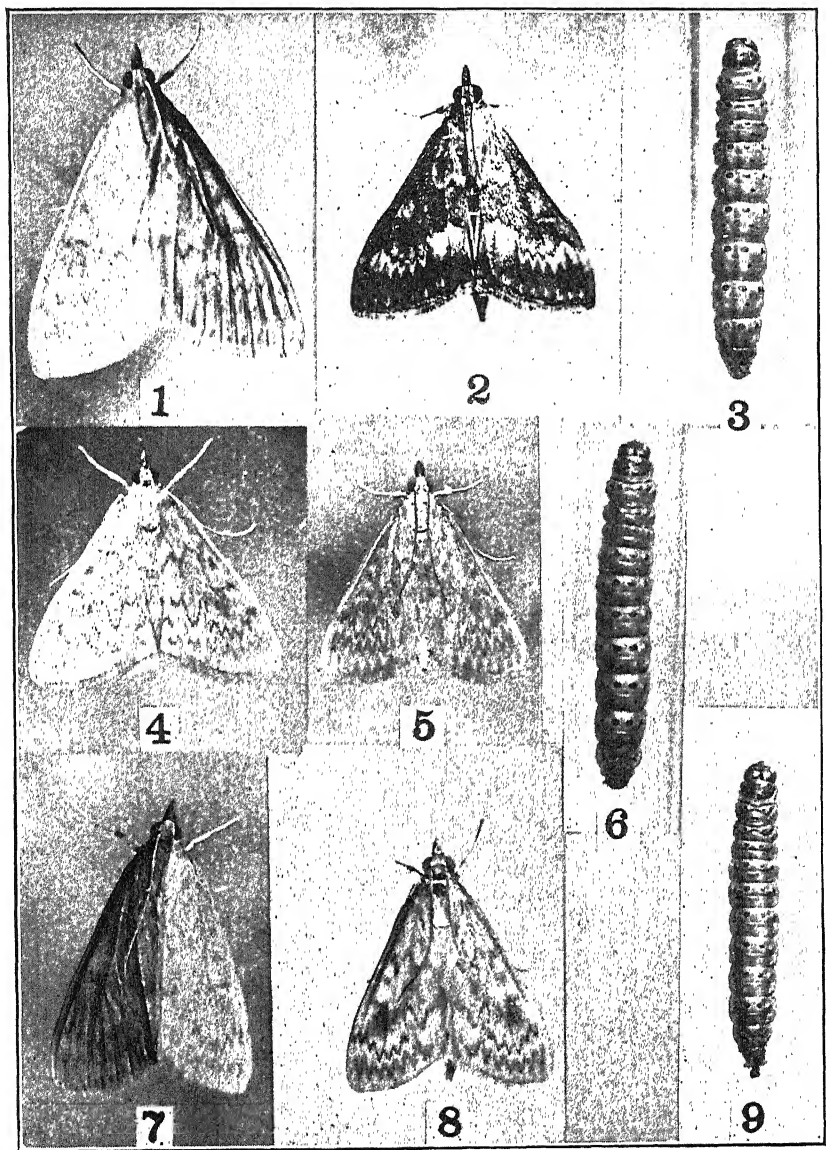
- Fig. 28. Glass vials with wire screen covers in which rearing of larvæ was carried on; also experiments on duration of pupation, and host preferences in confinement.
Fig. 29. Tin can for confining a definite number of larvæ to host material.
Fig. 30. Lantern-globe cage used in experiments on oviposition, etc.
Fig. 31. Plowing experiments, May, 1924.

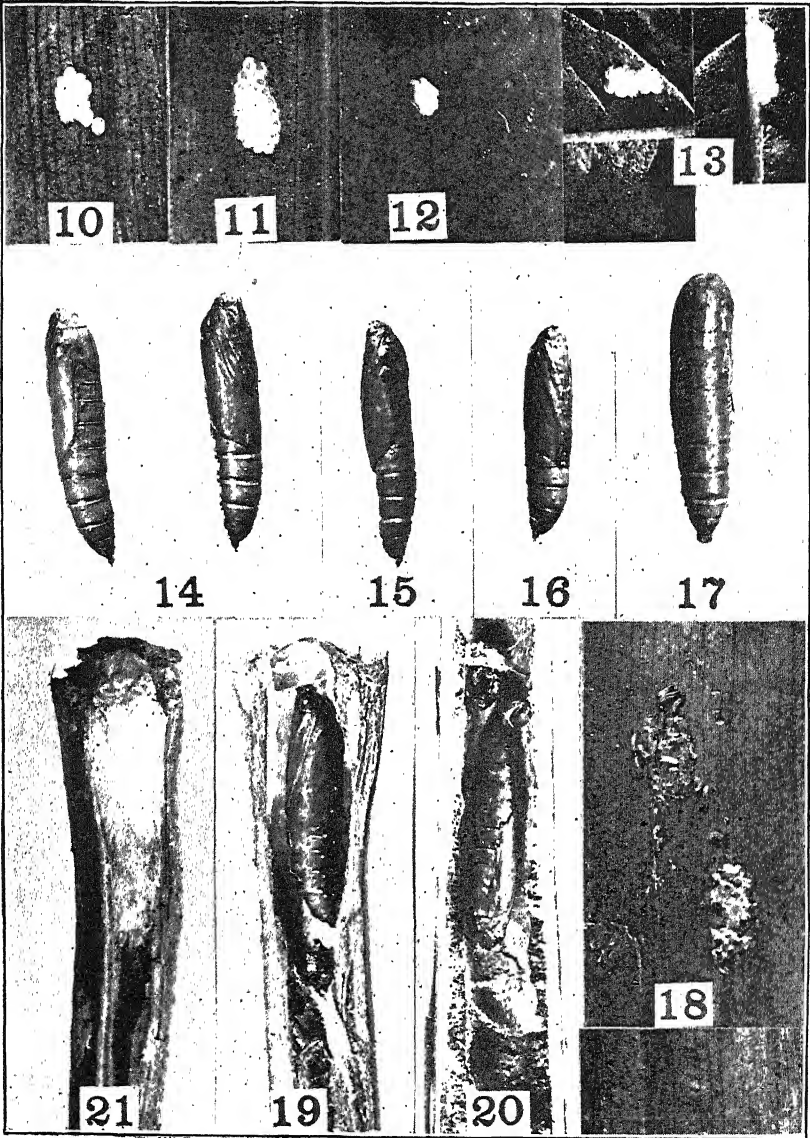
PLATE V.

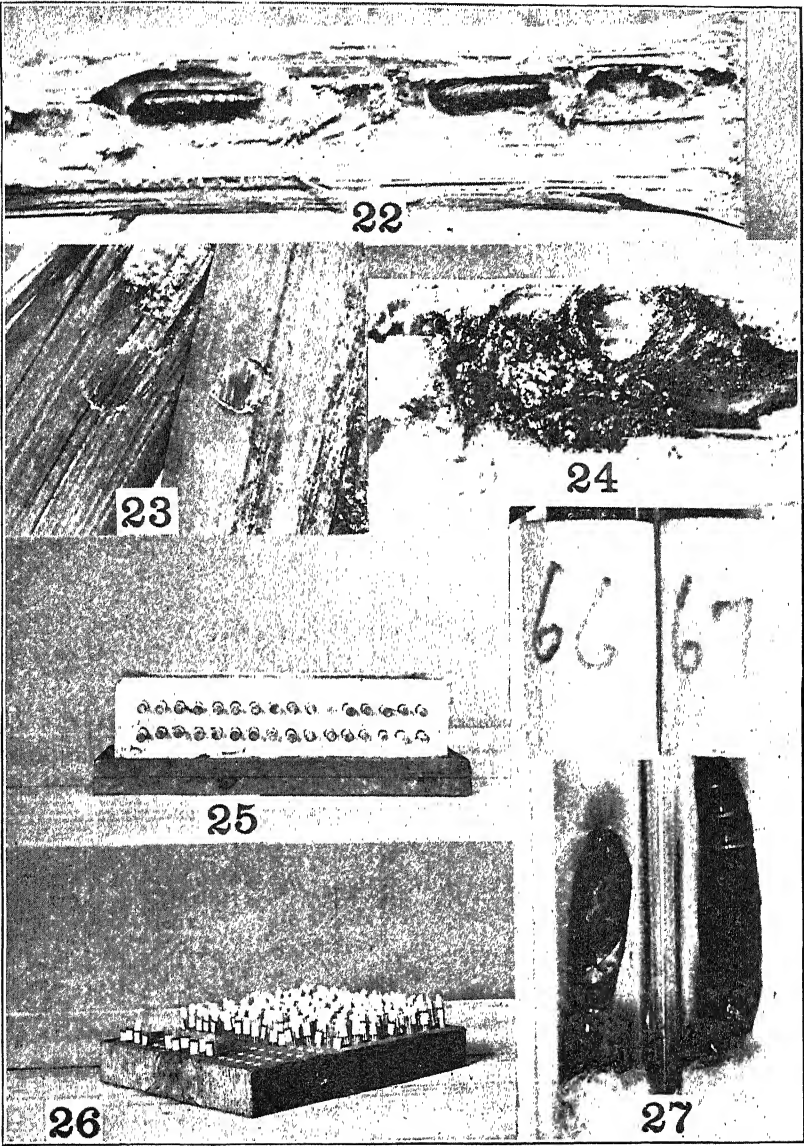
- Fig. 32. Sweet corn infested by *Pyrausta nubilalis*.
Fig. 33. Larva of *Pyrausta nubilalis* which has entered butt end of ear.
Fig. 34. Lotus plantation in Sandusky Bay. Note rolled-up leaf at right and also the general appearance of the damage to the leaves above the surface of the water, by *P. penitalis*.
Fig. 35. Floating leaf of lotus showing typical injury, to upper surface, in early stages, by *P. penitalis*.
Fig. 36. Distorted and dwarfed seed pods of lotus infested by *Pyrausta penitalis*.
Fig. 37. The pods shown in Figure 36 dissected to show pupa of *Pyrausta penitalis* and injury by the larva.

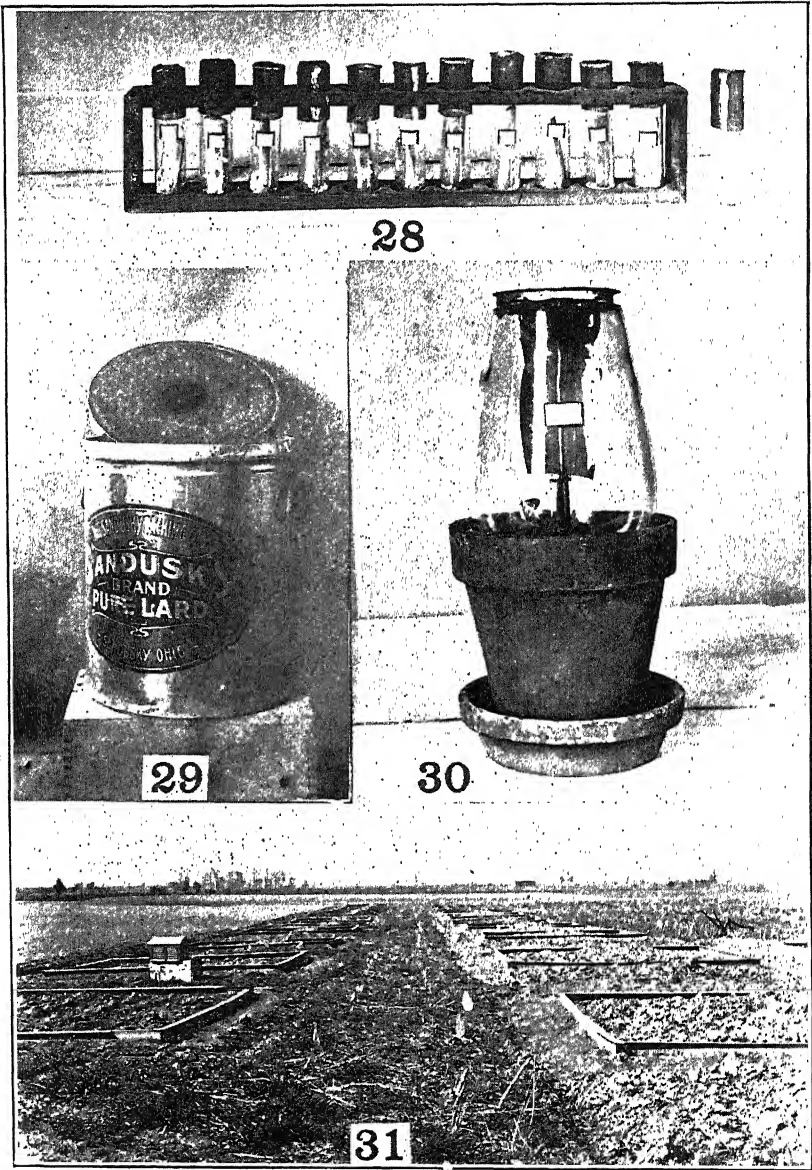
PLATE VI.

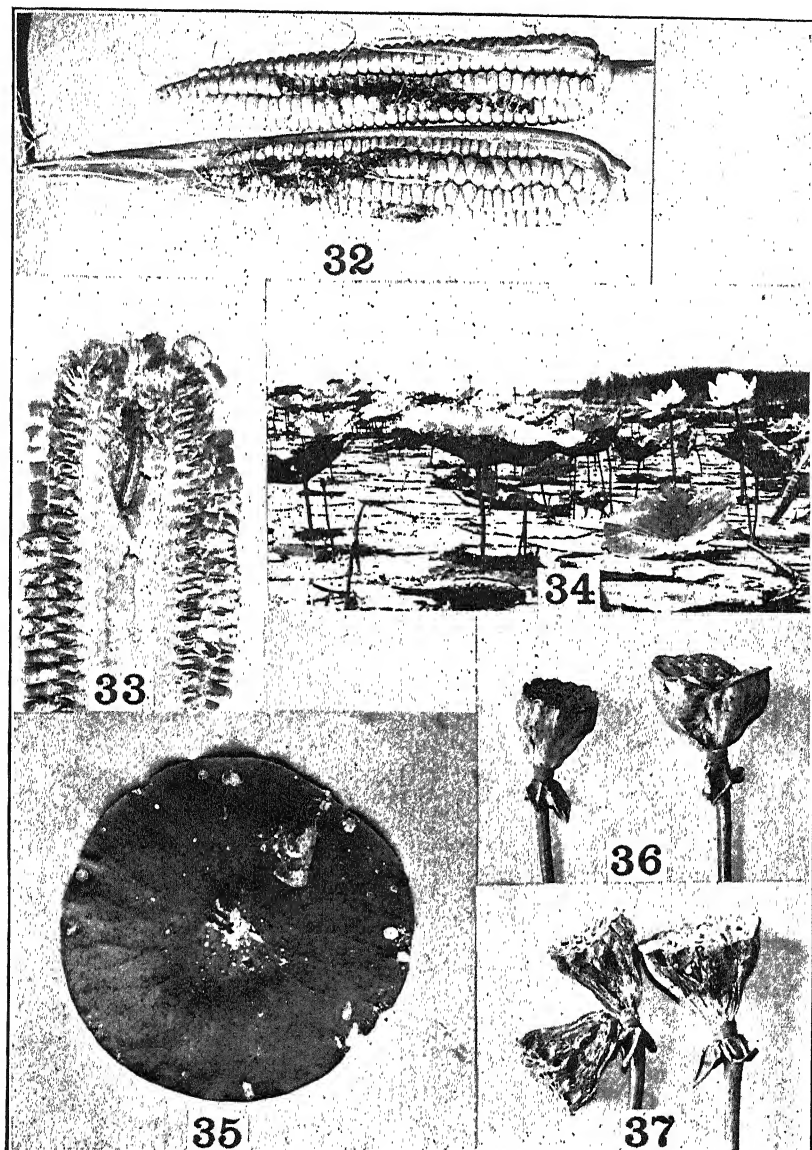
- Fig. 38. Injury to corn by *Pyrausta nubilalis*, showing typical breaking-over of the tassel which remained attached.
Fig. 39. Stems of smartweed dissected to show feeding tunnels made by larvæ of *Pyrausta ainsliei* and *penitalis*.
Fig. 40. Larvæ of *Pyrausta penitalis* feeding under their web on floating leaf of lotus. The white spots on the leaf at the left indicate places where the green epidermis has been removed by the larvæ.
Fig. 41. Characteristic injury to corn by *Pyrausta nubilalis* under conditions of sparse infestation. Note stalk at right with tassel broken over and frass attached to stalk immediately below.
Fig. 42. Stems of smartweed infested with *Pyrausta ainsliei*. Note entrance holes at every node.
Fig. 43. Cages used for overwintering material. Migration trap was placed around these cages, to prevent escape of larvæ.

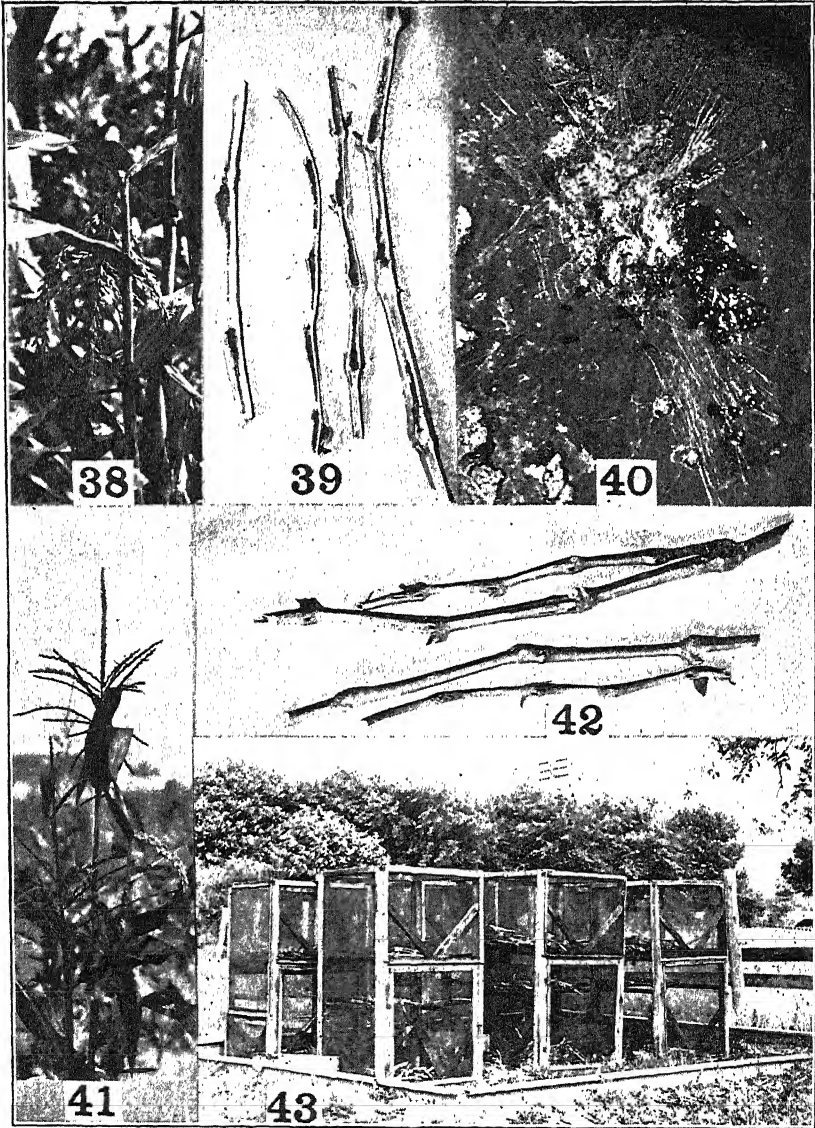












ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1926.*

JOHN H. SCHAFFNER,
Ohio State University

New distribution records of both genera and species continue to be made for the state. This is especially true of plants characteristic of the southern Appalachian Region. Numerous species of this flora extend in a broad triangle into Southern Ohio, some of them reaching northward to nearly the middle of the state. Great care is being taken to make these annual lists as accurate as possible so that they may be used with confidence in all studies dealing with the ecology, geography and floristics of the region covered.

12. *Polypodium polypodioides* (L.) Hitch. Gray Polypody. Leaning Rock, Clear Creek Road, Hocking Co. Robert B. Gordon.
18. *Pellaea atropurpurea* (L.) Link. Purple Cliff-brake. "Growing on sandstone outcrop about 3 ft. high." "Buffalo Beat," Buchtel, Athens Co. Len Stephenson.
20. *Asplenium pinnatifidum* Nutt. Pinnatifid Spleenwort. White's Gulch, Liberty Twp., Jackson Co. Mrs. Bayard Taylor. Also Vinton Furnance, Vinton Co., and Canters Caves, Jackson Co. Len Stephenson.
26. *Asplenium montanum* Willd. Mountain Spleenwort. White's Gulch, Liberty Twp., Jackson Co. Mrs. Bayard Taylor. Also Canters Caves, Jackson Co. Len Stephenson.
44. *Pteritis nodulosa* (Mx.) Nieuwl. American Ostrich-fern. Clear Creek, Hocking Co. Edward S. Thomas.
53. *Equisetum laevigatum* A. Br. Smooth Scouring-rush. Swanton Twp., Lucas Co. E. L. Moseley.
63. *Lycopodium complanatum* L. Trailing Club-moss. McConnells-ville, Morgan Co. Minnie M. Johnson.
156. *Eleocharis acuminata* (Muhl.) Nees. Flat-stemmed Spike-rush. Urbana Bog, Champaign Co. "Wettest part of bog." E. Lucy Braun.
171. *Eriophorum viridicarinatum* (Eng.) Fern. Thin-leaf Cotton-sedge. Urbana Bog, Champaign Co. E. Lucy Braun.
179. *Scleria triglomerata* Mx. Tall Nut-rush. Adams Co. (East edge). "Open ridge." E. Lucy Braun.
230. *Carex eburnea* Boott. Bristle-leaf Sedge. Cedar Fork, Adams Co. "Dry ridge in open woods." E. Lucy Braun.

*Papers from the Department of Botany, The Ohio State University, No. 184.

235. *Carex careyana* Torr. Carey's Sedge. Pemberton, Wood Co. "In a rich woods." E. L. Moseley.
245. *Carex crawei* Dew. Crawe's Sedge. Marblehead prairie, Ottawa Co. E. L. Moseley.
248. *Carex canoidea* Schk. Field Sedge. Swanton Twp., Lucas Co. E. L. Moseley.
265. *Carex haydeni* Dew. Hayden's Sedge. Whitehouse, Lucas Co. E. L. Moseley.
295. *Carex lupuliformis* Sartw. Hop-like Sedge. Summit Co. Collected in 1912 by V. Sterki. Specimen in Herbarium, Carnegie Museum, Pittsburgh. Otto E. Jennings.
334. *Eragrostis pectinacea* (Mx.) Steud. Purple Love-grass. "Common along the road near Blanchester," Clinton Co. Katie M. Roads.
345. *Korycarpus arundinaceus* Zea. American Korycarpus. Fort Ancient, Warren Co. Katie M. Roads.
347. *Triplasis purpurea* (Walt.) Chapm. Purple Sand-grass. On beach of Lake Erie. North Madison, Lake Co. John H. Schaffner, F. J. Tyler and R. B. Gordon.
352. *Arrhenatherum elatius* (L.) Beauv. Oat-grass. "Sown long ago and has spread near Maumee River 2 miles above Valmer's Park," Wood Co. E. L. Moseley.
- 372a. *Hordeum vulgare trifurcatum* Schlecht. Hooded Barley. Hillsboro, Highland Co. Katie M. Roads.
384. *Sporobolus vaginiflorus* (Torr.) Wood. Sheathed Rush-grass. Swanton, Lucas Co. E. L. Moseley.
- 391.1. *Agrostis perennans* (Walt.) Tuck. Upland Bent-grass. Marshal Twp., Highland Co. Katie M. Roads.
404. *Muhlenbergia tenuiflora* (Willd.) B. S. P. Slender Muhlenbergia. Fort Ancient, Warren Co. Katie M. Roads.
412. Change name to *Aristida longespica* Poir. (*A. gracilis* Ell.) and add, Hillsboro, Highland Co. Katie M. Roads.
416. *Phalaris canariensis* L. Canary-grass. "A weed in strawberry patch," Zanesville, Muskingum Co. W. G. Stover and H. A. Runnels.
- 423.1. *Panicum verrucosum* Muhl. Warty Panic-grass. Beaver Pond, Adams Co. "Moist clay banks." E. Lucy Braun.
426. *Panicum flexile* (Gatt.) Scrib. Wiry Panic-grass. Liberty and Marshal Twps., Highland Co., Katie M. Roads.
427. *Panicum philadelphicum* Bernh. Philadelphia Panic-grass. Near Hillsboro, Highland Co. Katie M. Roads.
440. *Panicum implicatum* Scrib. Slender-stemmed Panic-grass. Swanton Twp., Lucas Co. E. L. Moseley.
- 440.1. *Panicum meridionale* Ashe. Matting Panic-grass. Swanton Twp., Lucas Co. E. L. Moseley.
448. *Panicum boscii* Poir. Bosc's Panic-grass. Marshal Twp., Highland Co. Katie M. Roads.
452. *Syntherisma ischaemum* (Schreb.) Nash. Small Crab-grass. "Common in pasture lots and waste places." Liberty Twp., Highland Co. Katie M. Roads.

- 468.1. *Erianthus divaricatus* (L.) Hitchc. Long-haired Wooll-grass. "In an old field along Turkey Creek," Scioto Co. Conrad Roth.
- 489.1. *Muscari comosum* (L.) Mill. Blue-tufted Grape-hyacinth. "In an old pasture field." Near Buena Vista, Scioto Co. Escaped from cultivation, native of Europe. Conrad Roth.
499. *Chamaelirium luteum* (L.) Gr. Chamaelirium. Shawnee State Forest, Scioto Co. Mrs. Bayard Taylor. Also Conrad Roth.
500. *Triantha glutinosa* (Mx.) Baker. Glutinous Triantha. Swanton Twp., Lucas Co. E. L. Moseley.
541. *Juncus aristulatus* Mx. Small-headed Grass-leaf Rush. Washington Twp., Highland Co. Katie M. Roads.
542. *Juncus marginatus* Rostk. Grass-leaf Rush. Marshal Twp., Highland Co. Katie M. Roads.
- 557.1. *Iris germanica* L. Common Iris. "In a pasture field near Hillsboro," Highland Co. Katie M. Roads.
- 557.3. *Iris foliosa* Mack. & Bush. Leafy Blue-flag. Catawba Island, Ottawa Co. "Common at several points on the Catawba Island peninsula and was also seen, though not in flower, growing mixed with *Iris versicolor* in the Northwest corner of Middle Bass Island." Edgar Anderson. (The species in the Gray Herbarium from Toledo and listed as *I. hexagona* Walt. may be the same form. J. H. S.)
- 557.4. *Iris fulva* Ker. Red-brown Iris. "Escaped in a pasture along a brook from plants transplanted on the farm in former years." Near Mechanicsburg, Champaign Co. A. E. Waller.
- 561.1. *Sisyrinchium mucronatum* Mx. Michaux's Blue-eyed-grass. Marblehead prairie. Ottawa Co. E. L. Moseley.
589. *Ibidium ovale* (Lindl.) House. Small-flowered Lady's-tresses. Roosevelt Game Preserve, Scioto Co. A. R. Harper and Conrad Roth. Also Marshal Twp., Highland Co. Katie M. Roads.
593. *Periamium pubescens* (Willd.) MacM. Downy Rattlesnake-plantain. Hazelwood, Hamilton Co. Herbarium, University of Cincinnati. Belden Saur.
595. *Liparis liliifolia* (L.) Rich. Large Twayblade. Perry, Lake Co. Raymond A. Densmore.
- 602.1. *Hexalectris spicata* (Nutt.) Barnh. Crested Coral-root. Beaver Pond, Adams Co. "Open woods." E. Lucy Braun.
- 648.1. *Thalictrum revolutum* DC. Waxy Meadow-rue. Cedar Fork, Adams Co. "In openings." E. Lucy Braun.
- 657.1. *Berberis thunbergii* DC. Japanese Barberry. Escaped on a farm 5 miles southwest of Chardon, Geauga Co. John W. Baringer.
663. *Drosera rotundifolia* L. Roundleaf Sundew. Huron Co. R. W. Franks and C. F. Walker.
666. *Papaver rhoeas* L. Field Poppy. "Along a road near Hillsboro," Highland Co. Katie M. Roads.
676. *Adlumia fungosa* (Ait.) Greene. Climbing Fumatory. Thompson Ledges, Thompson, Geauga Co. F. J. Tyler, John H. Schaffner, and Robert B. Gordon.

682. *Berteroa incana* (L.) DC. Hoary Berteroa. Eaton, Preble Co. Carl N. Gibboney. Also Gambier, Knox Co. L. B. Walton.
- 686.1. *Draba cuneifolia* Nutt. Wedge-leaf Whitlow-grass. Two miles north of Locust Grove, Adams Co. "In fields on Cedarville dolomite." E. Lucy Braun.
699. *Lepidium densiflorum* Schrad. Wild Peppergrass. (L. apetalum Willd.) Northwest of Monclova, Lucas Co. E. L. Moseley.
703. *Thlaspi arvense* L. Field Penny-cress. Hamilton, Butler Co. "In alfalfa field" Ralph C. Smith. Also Portsmouth, Scioto Co., Conrad Roth; and Buchtel, Athens Co., Len Stephenson.
716. *Arabidopsis thaliana* (L.) Britt. Mouse-ear Cress. White's Gulch, Liberty Twp., Jackson Co. Mrs. Bayard Taylor. Also Old Man's Cave, Hocking Co. Mrs. Bayard Taylor, and also W. H. Camp.
730. *Arabis brachycarpa* (T. & G.) Britt. Purple Rock-cress. Swanton Twp., Lucas Co. E. L. Moseley.
- 742.3. *Leavenworthia uniflora* (Mx.) Britt. Michaux's Leavenworthia. Locust Grove, Adams Co. "Grassy rocky slopes." E. Lucy Braun.
764. *Erodium cicutarium* (L.) L' Her. Stork's-bill. "A weed in nursery stock." Mentor, Lake Co. "Mr. H. C. Beardslee says that this plant was introduced into Lake Co. many years ago in manure scraped from cattle cars by the freight agent at Painesville who used the manure on his garden." F. J. Tyler.
- 785.1. *Polygala incarnata* L. Pink Milkwort. Head of Beech Fork, Adams Co. "Openings, oak-hickory woods." E. Lucy Braun.
788. *Polygala polygama* Walt. Racemed Milkwort. Swanton Twp., Lucas Co. "Sandy field." E. L. Moseley.
830. *Hibiscus militaris* Cav. Halberd-leaf Rose-mallow. "Common along shores of islands in Maumee River." Otsego, Wood Co. E. L. Moseley.
- 875.1. *Viola cucullata* Ait. Marsh Blue Violet. Hocking Co. Rufus Crane.
884. *Viola sagittata* Ait. Arrowleaf Violet. Alum Creek, Delaware Co. Rufus Crane.
912. *Silene latifolia* (Mill.) Britt & Rend. Bladder Campion. Hillsboro, Highland Co. Katie M. Roads.
916. *Silene noctiflora* L. Night-blooming Catchfly. Urbana, Champaign Co. D. D. Dowds.
966. *Salsola pestifer* Nels. Russian-thistle. Lake shore, Geneva Harbor, Ashtabula Co. John H. Schaffner.
1002. *Guem flavum* (Porter) Bickn. Cream-colored Avena. Buckeye Lake, Licking Co. R. B. Gordon.
1009. *Potentilla recta* L. Upright Cinquefoil. Along roadside in Shaker Lake region, Cleveland, Cuyahoga Co. F. J. Tyler.
1015. *Comarum palustre* L. Purple Marshlocks. Huron Co. R. W. Franks and C. F. Walker.
- 1037.1. *Spiraea prunifolia* Sieb. & Zucc. Bridal-wreath. Native of Japan and China. "Growing in a pasture lot" near Hillsboro, Highland Co. Katie M. Roads.

1088. *Prunus avium* L. Sweet Cherry. Near Hillsboro, Highland Co. Katie M. Roads.
1104. *Baptisia leucantha* T. & G. Large White Wild-indigo. Hamer Twp., Highland Co. Collected by Joesph and Paul Wilkin. Katie M. Roads.
1116. *Trifolium arvense* L. Rabbit-foot Clover. Brown Twp., Knox Co. R. B. Gordon and John H. Schaffner.
1122. *Lotus corniculatus* L. Bird's-foot Trefoil. Persistent after cultivation. Columbus, Franklin Co. John H. Schaffner.
1138. *Meibomia pauciflora* (Nutt.) Ktz. Few-flowered Tick-trefoil. Fort Ancient, Warren Co. Katie M. Roads.
- 1138.1. *Meibomia arenicola* Vail. Sand Tick-trefoil. Swanton Twp., Lucas Co. E. L. Moseley.
1152. *Lespedeza procumbens* Mx. Trailing Bush-clover. Marshal Twp., Highland Co. Katie M. Roads.
1170. *Lathyrus palustris* L. Marsh Pea. Huron Co. R. W. Franks and C. F. Walker.
- 1177.1. *Galactia volubilis* (L.) Britt. Downy Milk-pea. Cedar Fork, Adams Co. "Dry soil openings." E. Lucy Braun.
1178. *Phaseolus polystachyus* (L.) B. S. P. Wild Bean. Turkey Creek, Adams Co. "In thickets." E. Lucy Braun.
1229. *Acer spicatum* Lam. Mountain Maple. "In very deep shaded ravine south of Little Mountain," Geauga Co. F. J. Tyler.
1284. *Betula alba* L. European White Birch. "A large and well established colony at Fovargue's Beach, Lake Erie; growing both in the sand of the beach and on the higher ground back." Perry, Lake Co. F. J. Tyler.
1329. *Ribes odoratum* Wendl. Buffalo Currant. Buchtel, Athens Co. Len Stephenson.
1344. *Raimannia laciniata* (Hill.) Rose. Cutleaf Evening-primrose. "In an oats field and also in two adjoining pasture lots near" Hillsboro, Highland Co. Katie M. Roads.
1359. *Cucurbita maxima* Duchesne. Squash. Near Hillsboro, Highland Co. Katie M. Roads.
1394. *Azalea nudiflora* L. Pink Azalea. Hocking Co. Len Stephenson.
1403. *Gaultheria procumbens* L. Creeping Wintergreen. "On north and west facing weathered shale slope." Flint ravine, Sharon Twp., Franklin Co. A. E. Waller.
1412. *Oxycoccus macrocarpus* (Ait.) Pursh. Large Cranberry. Huron Co. R. W. Franks and C. F. Walker.
1415. *Diospyros virginiana* L. Persimmon. Near Lake Erie, North Madison, Lake Co. Apparently native and thus the farthest northern occurrence in Ohio. Originally a large patch of old trees, now mostly cut down, those remaining forming an irregular row along the road. F. J. Tyler and John H. Schaffner.
1427. *Ipomoea hederacea* Jacq. Ivyleaf Morning-glory. Buchtel, Athens Co. Len Stephenson.
- 1433.1. *Convolvulus repens* L. Trailing Bindweed. Cedar Falls, Adams Co. "In fields." E. Lucy Braun.
1464. *Gentiana quinquefolia* L. Stiff Gentian. Greenbrier district, Adams Co. "Fairly common." Conrad Roth.

1467. *Gentiana saponaria* L. Soapwort Gentian. Near Portsmouth, Scioto Co. Conrad Roth.
1468. *Gentiana andrewsii* Griseb. Closed Gentian. Near Gallipolis, Gallia Co. Conrad Roth.
1470. *Gentiana villosa* L. Striped Gentain. Roosevelt Game Preserve, Scioto Co. A. R. Harper and Conrad Roth.
1488. *Asclepias amplexicaulis* Sm. Bluntleaf Milkweed. Swanton Twp., Lucas Co. E. L. Moseley.
1554. *Aureolaria virginica* (L.) Pennell. Downy False Foxglove. (*Dasystoma flava* (L.) Wood. *Gerardia flava* L. of authors). Swanton Twp., Lucas Co. E. L. Moseley.
1555. *Aureolaria flava* (L.) Farw. Smooth False Foxglove. (*Dasystoma virginica* (L.) Britt. "Rich woods" South of Delaware, Delaware Co. Robert B. Gordon.
1560. *Otophylla auriculata* (Mx.) Small. Auricled *Gerardia*. Lakeside, Ottawa Co. Collected in 1898. May E. Day.
1564. *Melampyrum lineare* Lam. Narrow-leaf Cow-wheat. Holland, Lucas Co. E. L. Moseley.
1577. *Anisostichus capreolata* (L.) Bur. Cross-vine. Along little Scioto River. Scioto Co. A. R. Harper and Conrad Roth.
1584. *Utricularia minor* L. Lesser Bladderwort. Champaign Co. Herbarium, University of Cincinnati. E. Lucy Braun.
1598. *Myosotis virginica* (L.) B. S. P. Virginia Forget-me-not. "Buffalo Beat," near Buchtel, Athens Co. Len Stephenson
1607. *Echium vulgare* L. Blueweed. Clifton Gorge, Greene Co. Robert B. Gordon. This species is apparently general in the state but no specimens from the northwestern part.
1636. *Satureia hortensis* L. Summer Savory. Buchtel, Athens Co. Len Stephenson.
1645. *Thymus serpyllum* L. Creeping Thyme. Perry, Lake Co. "A large and increasing colony growing in the shade of trees near the old Green nursery cellar, South Ridge Road." F. J. Tyler.
- 1663.1. *Meehania cordata* (Nutt.) Britt. Meehania. "Shaded rocky bank of Turkey Creek." Opposite entrance to Roosevelt Game preserve, Scioto Co. Mrs. Bayard Taylor.
1686. *Salvia lyrata* L. Lyreleaf Sage. Shawnee State Forest, Scioto Co. Mrs. Bayard Taylor.
1725. *Zizia cordata* (Walt.) DC. Heartleaf Meadow-parsnip. "Buffalo Beat," Buchtel, Athens Co. Len Stephenson.
- 1776.1. *Viburnum molle* Mx. reported last year is probably *V. scabrellum* T & G Chapm.
1777. *Viburnum dentatum* L. Toothed Arrow-wood. Huron Co. R. W. Franks and C. F. Walker.
- 1786.1. *Triosteum aurantiacum* Bickn. Scarlet-fruited Horse-gentian. "On a wooded hillside" at Fort Ancient, Warren Co. Katie M. Roads.
1807. *Valeriana pauciflora* Mx. Large-flowered Valerian. Buchtel, Athens Co. Len Stephenson.
1817. *Lobelia puberula* Mx. Downy Lobelia. White's Gulch, Liberty Twp., Jackson Co. Mrs. Bayard Taylor.

- 1822.1. *Scabiosa atropurpurea* L. Mourning-bride. Accidental in a vacant lot, Hillsboro, Highland Co. Katie M. Roads.
1847. *Helianthus mollis* Lam. Hairy Sunflower. Madison, Lake Co. Earl Dodge and F. J. Tyler.
1903. *Chrysopsis mariana* (L.) Nutt. Maryland Golden-aster. White's Gluch, Liberty Twp., Jackson Co. Mrs. Bayard Taylor.
1906. *Solidago flexicaulis* L. Zig-zag Goldenrod. Portsmouth, Scioto Co. Conrad Roth.
1908. *Solidago hispida* Muhl. Hairy Goldenrod. Portsmouth, Scioto Co. Conrad Roth.
1911. *Solidago speciosa* Nutt. Showy Goldenrod. Portsmouth, Scioto Co. Conrad Roth.
1931. *Aster divaricatus* L. White Wood Aster. Ft. Ancient, Warren Co. Also in Marshal Twp., Highland Co. Katie M. Roads.
1936. *Aster lowrieanus* Port. Lowrie's Aster. North of Alton, Franklin Co. R. B. Gordon.
1944. *Aster oblongifolius* Nutt. Aromatic Aster. Minford, Scioto Co. Conrad Roth.
1976. *Eupatorium aromaticum* L. Smaller White Snakeroot. Turkey Creek, Scioto Co. Conrad Roth.
1979. *Lacinaria squarrosa* (L.) Hill. Scaly Blazing-star. Green Brier District, Adams Co. Conrad Roth.
1982. *Lacinaria scarioso* (L) Hill. Large Blazing-star. Green Brier District, Adams Co. Conrad Roth.
1983. *Lacinaria spicata* (L.) Ktz. Dense Blazing-star. Beaver Pond, Adams Co. "In meadows." E. Lucy Braun. Also Green Brier District, Adams Co. Conrad Roth.
2014. *Senecio pauperculus* Mx. Balsam Squaw-weed. Adams Co. Herbarium, University of Cincinnati. E. Lucy Braun.
- 2014.1. *Senecio glabellus* Poir. Cress-leaf Groundsel. Eaton, Preble Co. Carl N. Gibboney.
2023. *Cirsium virginianum* (L.) Mx. Virginia Thistle. Adams Co. Herbarium University of Cincinnati. E. Lucy Braun.
- 2026a. *Cirsium arvense integrifolium* Wimm. & Grab. North Olmstead, Cuyahoga Co. Freda Detmers.
2039. *Soucheus arvensis* L. Field Sow-thistle. Variety without glandular bristles on the peduncles and involucre. Railway near Madison avenue crossing, Painesville, Lake Co. F. J. Tyler.
2046. *Lactuca sagittifolia* Ell. Arrowleaf Lettuce. Fort Ancient, Warren Co. Katie M. Roads.
2047. *Lactuca villosa* Jacq. Hairy-veined Blue Lettuce. Marshal Twp., Highland Co. Katie M. Roads.
2056. *Hieracium paniculatum* L. Panicked Hawkweed. Marshal Twp., Highland Co. Katie M. Roads.
2058. *Hieracium gronovii* L. Gronovius' Hawkweed. Marshal Twp., Highland Co. Katie M. Roads.
2063. *Hieracium aurantiacum* L. Orange Hawkweed. Lake Aquilla, South of Chardon, Geauga Co. John H. Schaffner and Robert B. Gordon.

THREE NEW SPECIES OF ENICOCEPHALIDAE.*

C. J. DRAKE

AND

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In working over some miscellaneous Hemiptera the writers have found three apparently undescribed species of *Systelloderus*. One of these was taken in a "concentration box" where it had been observed feeding on adults of the hessian fly.

Systelloderus inusitatus, n. sp.

Moderately stout, sparsely clothed with fine hairs, brownish, the legs and antennæ lighter. Head shiny, anterior lobe elongate, posterior lobe slightly broader than long, its width scarcely greater than that of anterior lobe through eyes. Eyes fairly prominent, reddish. Ocelli small. Antennæ moderately long, stout, clothed with numerous long hairs, the proportional length of the segments—I:II:III:IV: :5:12:11:11. Rostrum short, stout.

Pronotum shiny, narrowed anteriorly, the anterior and posterior lobes short, about equal in length; intermediate lobe longer than the other two taken together (median measurement); the base distinctly emarginate. Scutellum rather dull, blunt at the apex, the hairs very sparse. Elytra semi-opaque, the margins and veins fringed with yellowish hairs. Anterior legs very stout, laterally compressed; posterior legs slender; anterior tibiæ strongly widened at the apex, armed there with five sharp spines; tarsi with two sharp recurved claws. Abdomen dark stramineous, tinged with brownish. Length 2.87 mm.; width .53 mm.

Described from a single specimen taken by C. J. Drake from beneath the bark of a fallen tree at Woodville, Mississippi, July 16, 1921, in authors' collection. The characters of the head and pronotum distinguish this form from allied species.

Systelloderus iowensis, n. sp.

Allied to *S. angustatus* Champ. but distinguished from it by the lighter color, the moderately hairy head and pronotum and the angularly emarginate posterior margin of the pronotum.

Pale brown, slightly shining, moderately hairy; posterior lobe of the head slightly broader than long, the ocelli fairly prominent. Pronotum

*Contribution from Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

narrowed anteriorly, the anterior and intermediate lobes sulcate down the middle. Legs pale testaceous, moderately hairy; elytra testaceous, their margins beset with yellowish hairs.

Other characters similar to *S. angustatus*. Length 3.15 mm., width .66 mm.

Holotype, Onawa, Iowa, Sept. 18, 1923, F. A. Fenton, collector. *Paratype*, taken with type. Both specimens were taken in a "concentration cage" and records indicate that they were feeding on the emerging adults of the hessian fly, *Mayetiola destructor* Say. *Type* in collection of Iowa State College. *Paratype* in the authors' collection.

Sytelloderus terrenus, n. sp.

Elongate, shiny, moderately clothed with fine yellowish hairs; testaceous; the abdomen dull, dark stramineous to dirty brown. Head elongate, anterior portion nearly cylindrical, twice as long as posterior portion; posterior portion distinctly broader than long, the sides rounded, slightly depressed in the middle. Eyes reddish, not very prominent. Ocelli small. Antennæ pale, clothed with fine hairs, segments I and IV stoutest, the length of the segments in the proportion—I:II:III:IV: : 5:12:13:12:. Rostrum short, stout, sub-equal to anterior portion of head in length.

Pronotum at the middle nearly twice as wide as the head, slightly narrowed posteriorly, with a distinct longitudinal median depression, the base not emarginate, the intermediate and posterior lobes not distinctly separated from one another. Elytra shiny, very short (brachypterous), about twice as long as the pronotum, distinctly and deeply transversely sulcate slightly beyond the apex of the scutellum, veins absent. Legs stout, especially the anterior pair; claws long, sharp, recurved. The anterior tibiæ strongly widened toward the apex and armed there with several long spurs. Abdomen with a few long hairs at the apex. Length 3 mm.; width .45 mm.

Described from a single short winged specimen taken on soil in a truck garden, Burlington, Iowa, July 18, 1925, by H. M. Harris.

Any of the above species may be separated from *S. biceps* Say by the more incrassate anterior femora, the anterior tibiæ being more enlarged and much broader at the apex and the eyes being smaller and less coarsely granulate.

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SEX-LIMITED CHARACTERS AND ALLOSOME- LINKED HEREDITY*.

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In developing a general theory of sex, it is necessary to consider all the fundamental phenomena of sexuality which occur in all the diverse types of plants and animals with their diverse types of life cycles, times of chromosome reduction, and diploid and haploid generations, otherwise a very incomplete or improper view of the subject will surely be obtained. Sexual dimorphisms, or sex limited characters are present from very low types of plants and animals and continue to the highest representatives of both kingdoms. The general nature of sex-limited characters differs in no wise in the higher forms from the lower except that the higher may have a much greater complexity of hereditary factors that may be influenced by the sexual state in their expression.

The presence of allosomes in a few plants and in apparently all of the higher animals complicates the study of sexuality and must be carefully considered, as well as the mode of transmission of the hereditary potentialities, if proper deductions are to be made as to the nature of sexuality in such forms. Heteromorphic allosome mates plainly have differences in hereditary factors and since these chromosomes have a peculiar and usually definite distribution in relation to the sex of the individual, they give rise to characteristic sex-limited sex-influenced, and sex-associated characters.

It is the intention to present in a very brief way an explanation of certain phenomena from the standpoint of the functional nature of sex in order to make clear to students who deal

*Papers from the Department of Botany, the Ohio State University, No. 182.

mainly with plant materials that there is nothing in the animal series that is incompatible with a consistent theory of sexuality as it is developed in plants and in lower animals. The writer has found that much confusion of mind does exist, obtained mainly from impossible hypothetical explanations of certain common types of animal heredity. These hypotheses have been highly elaborated and may appear quite plausible to one unacquainted with a great array of facts and phenomena of sexuality met with not only in plants but also in the lower animals, which flatly contradict the hypotheses and which their advocates have never attempted to consider.

Since heredity is a manifestation of the protoplast, a cytological interpretation must be developed as the basis of all speculations which go beyond observation. But since the hereditary character is the result of an expression through physiological activity, it follows that the dead cell inclusions and the physical state of the protoplasm itself at the time of expression may have a decided effect on the character developed. Now since sexuality is a condition or state of the individual, organ, cell, or chromosome, which may come and go and which can be reversed, it follows that the sexual characteristics of an individual may not always correspond to the actual allosome constitution, present. But whether allosomes are present or not, tissues or individuals genetically the same may show entirely different sexual characters in different parts of the body, depending on which sexual state is present during the development of the part. Such characters distinctive of male or female individuals or of parts of hermaphroditic individuals are sex-limited characters. The first step in developing an adequate conception of sex-limited characters is to study the dimorphisms in hermaphrodites and bisporangiate individuals and then proceed from the basis established to the dimorphisms of unisexual and monosporangiate individuals. Sex-limitation in monocious sporophytes may consist in the presence of a character or its complete or nearly complete suppression through one sexual state or the other, as for example the awn on the lemma of *Zizania aquatica* which is present on the carpellate spikelet but undeveloped on the staminate spikelet. In other cases there is merely a degree of difference of development or expression, as in *Cocos nucifera* in which the sepals of the staminate flowers are small and those of the carpellate flowers much larger; or as in the inflorescence of *Sicyos angulatus*

where the staminate inflorescence has a long peduncle and the carpellate inflorescence a short one. There are exactly similar differences in cases of unisexual and monosporangiate individuals. For example in Dorset sheep, the female has little horns and the male large ones, while in the Merino the males have horns and females have none. In *Carica papaya*, a diecious plant, the staminate corollas are sympetalous and the carpellate corollas are choripetalous. In the diecious *Acnida tamariscina*, the staminate flowers have a five-sepaled calyx, while the carpellate flowers have none.

Characters that are sex-limited may have their factors or potentialities either in the autosomes or in the allosomes. Recently it has become the vogue, in some quarters to rechristen the allosomes as "sex-chromosomes" and the characters, whether sex-limited or not, which have their potentialities in the allosomes as "sex-linked" characters. Now all chromosomes of sexual organisms are sexual chromosomes. There are no special factors or determiners for sex, nor sex-linked factors properly speaking. There is no "sex-linked heredity". Such terminology can only arise out of ignorance of sexuality as it is evolved in the organic kingdom and leads only to confusion and misunderstanding of things as they actually exist. Both terms are wrong because they tend to perpetuate an inadequate hypothesis of sexuality as well as a false notion as to the distribution of sexual characters. For example, when we say that ordinary Daltonism is "sex-linked" the term might naturally imply that the color-blindness was confined to one sex. But women are color-blind as well as men. Furthermore, when there is sex reversal, whether affecting the primary or secondary sexual state, the so-called "sex-chromosomes" do not at all indicate the sex of the cell or individual. The terms are improper also from the point of view of sexuality itself, since they imply that sex is a matter of Mendelian or chromosome heredity. The common occurrence of sex-reversal in both directions and the fact that commonly in plants the sex is not determined nor changed when the chromosomes, with their Mendelian heredity, are segregated show that fundamentally sex is primarily a thing apart from Mendelian heredity. Nor is sex usually determined in plants when chromosomes are aggregated in fertilization. In all vascular plants except the comparatively rare unisexual gametophytes of the homosporous pteridophytes and the diecious sporophytes of seed plants, both male and

female conditions arise from the same chromosome complex in the same individual, and furthermore, as stated, the sex can frequently be reversed in either direction in both haploid gametophytes and diploid sporophytes.

Sphaerocarpus seems to be the only known case in both the plant and animal kingdoms, where allosomes presumably might control or determine directly the primary sexual state and structures in a haploid organism, and here these states follow the presence of the secondary sexual states in the gametophytes. In animals as in the plants where such bodies are present, the segregated allosomes seem to have no influence whatever on the development of the primary sexual states or on the development of the primary sexual structures of the gametes. Then what is the basis for the assumption of a fundamental influence in the zygote?

From a correct, evolutionary point of view it is evident that the allosome condition is the result of sexuality rather than its cause. It is only in the most extreme type of sex-determination in the gametophyte, where the sex is determined in the spore, that a differential distribution of chromosomes could arise, which could influence functional states; and in the final development of dieciousness, there is again a condition established in which allosomes with differential heredities could be evolved and continued in a definite sex-association in the individual.

At most, allosomes might be the cause of the diecious conditions or of some unisexual individuals whether diploid or haploid; but this is only one of the special aspects of sexuality, not the important problem to be solved, either of primary sexual states and characters, or of secondary states and characters. It must be remembered that sexual dimorphism is just as wide-spread and prominent in the individual in species without evident allosomes, like the hemp for example as in species with allosomes (See Schaffner 19, 22, and McPhee 10.) But allosomes are not at all an explanation of unisexuality; for all of the 150,000 species of heterosporous plants have unisexual gametophytes, and in not a single one of these has the unisexual condition any relation to allosomes. The very nature of the life cycle makes such a relation impossible.

So far as we have present knowledge, we can have chromosome-linked heredity or factors and perhaps cytoplasm-linked and plastid-linked heredity. Chromosome heredity falls into

two categories, autosome-linked heredity and allosome-linked heredity, but the hereditary factors or potentialities of autosomes and allosomes are essentially the same in nature, since organisms with allosomes show nothing fundamentally different from those which have no such bodies.

Sex-limited characters are physiological as well as morphological. The instinctive characters peculiar to one sex or the other are readily reversible, as has been known for a long time, as well as the morphological characters. Now if our notions of Mendelian heredity are correct, all sex characters which are of a unitary nature must in the end be due to one or more hereditary factors. These factors, as understood at present, are presumably chromosome-linked; that is, they are properties of certain chromosomes or parts of chromosomes. For convenience we can assume that they are in the chromatin granules as Mottier (15) suggested in 1907.

As intimated before, the autosome-linked factors give rise to one type of sex-limited characters and the expression is the same whether it occurs in either hermaphroditic or bisporangiate individuals on the one hand, or in unisexual or monosporangiate individuals on the other. Whenever a given sexual state is present, the factors in the autosomes express a peculiar character or group of characters that we recognize as male or female as the case may be. The expression changes with the change of sexual state. This is evident both in monocious plants and in reversed diecious individuals.

Since the allosomes show a peculiar distribution in relation to the sex of the individual any factors they may have may show a peculiar association with one sex or the other, while characters which have their potentialities in the autosomes will show no special associative peculiarities in relation to either sex when Medelian segregation occurs. Any factors in the allosomes subject to sex-limitation can, of course, only show the characters where they are actually present in the proper sexual state. Such characters are sex-limited characters of allosome-linked heredity. Allosomes may have heredity not sex-limited the same as have the autosomes. Such heredity will show a peculiar distribution in relation to sex in reciprocal crosses.

The writer does not wish to discuss in all its details the probable cause for the definite distribution of allosomes in relation to male and female sex, but it can be definitely stated that this condition, whether ascribed to specific, differential

attraction or whether we assume that the allosomes are sex-producing through their influence on the functional activity of the cell, is not at all antagonistic to the physiological theory of sex. Because of the ease with which certain allosome-bearing plants and animals change their sexual states under certain conditions, the writer inclines strongly to the differential compatibility hypothesis at the present time. The assumption of a greater or less degree of specific compatibility or incompatibility and of a consequent specific attraction and selective union of gametes with allosome differences together with a changing metabolic gradient modifying the primary sexual state of the eggs of heterogamous organisms brings the situation as presented by the allosome-bearing organisms into complete harmony with that found in hermaphrodites and bisporangiate sporophytes of the various types as well as with that found in those strongly dimorphic unisexual and diecious species, in which no allosomes are present. The nature of sex-determination in relation to allosome will be further discussed below in connection with the special problems of allosome heredity and sex-limited characters.

Since X and $2X$ are established symbols in an extensive botanical literature and are still almost universally used by botanists to designate the haploid and diploid complements of chromosomes, X and Y cannot properly be employed as symbols for allosomes without causing an endless amount of confusion in both morphology and genetics. In the present paper A and B will be used as symbols instead of the much used but confusing symbols " X " and " Y " and " W " and " Z ". " A " represent the allosome which in diploid individuals is normally associated with either sex; " B " represents the allosome which in diploid individuals is normally associated with but one sex. Whenever we have the allosome formulæ ♀ AA and AB ♂, or ♀ AB and AA ♂, or ♀ Ao and AA ♂ there is apparently indiscriminate migration of the A allosome to either sex, just as in the case of autosomes, but the B allosome under the normal conditions is associated with a single sex, either the male only or the female only.

Although there are many peculiar types of allosome constitution, the most common types of animals and plants in relation to the allosome condition are the seven presented below. A and B represent the allosomes, and X the haploid complement of autosomes or the chromosomes in general when no allosomes are present.

I. MAN, DROSOPHILA, etc. (See Painter (20) and Stevens (29).

♀ $\frac{AA}{xx}, \frac{AB}{xx}$ ♂. Diploid individuals.

Eggs = $\frac{A}{x}$, $\frac{B}{x}$. Determined as ♀ $\frac{A}{x}$ and $\frac{A}{x}$ ♂.

Sperms = $\frac{A}{x}$, $\frac{B}{x}$.

In some mammals decided reversals of secondary sexual characters have been observed.

II. ABRAXAS. (Probably). No cytological difference visible. (See Doncaster (4).

♀ $\frac{AB}{xx}, \frac{AA}{xx}$ ♂. Diploid individuals.

Eggs = $\frac{A}{x}$, $\frac{B}{x}$. Determined as ♂ $\frac{A}{x}$ and $\frac{B}{x}$ ♀.

Sperms = $\frac{A}{x}$, $\frac{A}{x}$.

In this allosome type remarkable sex-intergrades have been developed by crossing species. (See Goldschmidt (7).

III. CHICKEN. (See Guyer (9).

♀ $\frac{Ao}{xx}, \frac{AA}{xx}$ ♂. Diploid individuals. o = zero.

Eggs = $\frac{A}{x}$, $\frac{o}{x}$. Determined as ♂ $\frac{A}{x}$ and $\frac{o}{x}$ ♀.

Sperms = $\frac{A}{x}$, $\frac{A}{x}$.

Decided sex reversals observed; female individuals reversed to secondary male state and even to the normally functioning primary male state; males, so far, reversed to secondary female state only.

IV. SPHAEROCARPUS. (Plant). (See Allen (1).

Sporophyte = $\frac{AB}{xx}$ Neutral. Diploid individuals.

Spores = $\frac{A}{x}$, $\frac{B}{x}$. Determined as ♀ $\frac{A}{x}$ and $\frac{B}{x}$ ♂.

Gametophytes = ♀ $\frac{A}{x}$, $\frac{B}{x}$ ♂. Haploid individuals.

Gametes = ♀ $\frac{A}{x}$, $\frac{B}{x}$ ♂.

No sex reversal known.

V. EUISETUM ARVENSE and OSTRICH-FERN. (See Wuist (32). No allosomes present.

Sporophyte = $\frac{oo}{xx}$ Neutral Diploid individuals.

Zero (o) = absence of allosome.

Spores = $\frac{o}{x}$, $\frac{o}{x}$. Determined as ♀ $\frac{o}{x}$ and $\frac{o}{x}$ ♂.

Gametophytes = ♀ $\frac{o}{x}$, $\frac{o}{x}$ ♂. Haploid individuals.

Gametes = ♀ $\frac{o}{x}$, $\frac{o}{x}$ ♂.

Complete primary and secondary sex reversal easily brought about; female to male and male to female. The male to female reversal much less frequent than the reciprocal reversal.

VI. *CANNABIS SATIVA*. (See McPhee (14). No allosomes present.

Sporophyte = $\delta \frac{oo}{xx}, \frac{oo}{xx} \sigma^o$. Diploid individuals strongly sexually dimorphic.

Spores = $\varphi \frac{o}{x} |, \frac{o}{x} \varphi$. Megaspores with secondary sexual dimorphism

and $\sigma^o \frac{o}{x} |, \frac{o}{x} \sigma^o$. Microspores with secondary sexual dimorphism.

Gametophytes = $\varphi \frac{o}{x} |, \frac{o}{x} \varphi$ and $\sigma^o \frac{o}{x} |, \frac{o}{x} \sigma^o$. Haploid individuals very strongly sexually dimorphic.

Gametes = $\varphi \frac{o}{x} |, \frac{o}{x} \sigma^o$. Primary sexual state.

Female gametes before or after fertilization = $\varphi \frac{o}{x} |, \frac{o}{x} \sigma^o$.

Both partial and complete sex-reversal easily brought about, carpellate to staminate and staminate to carpellate.

VII. *HUMULUS JAPONICUS*. (See Winge (31).

Sporophytes = $\delta \frac{AA}{xx}, \frac{AB}{xx} \sigma^o$. Diploid individuals slightly sexually dimorphic, decidedly so as to the inflorescence.

Spores = $\varphi \frac{A}{x} |, \frac{A}{x} \varphi$ and $\sigma^o \frac{A}{x} |, \frac{B}{x} \sigma^o$.

Gametophytes = $\varphi \frac{A}{x} |, \frac{A}{x} \varphi$ and $\sigma^o \frac{A}{x} |, \frac{B}{x} \sigma^o$. Supposed allosomes have no influence on the sex of the gametophyte.

Gametes = $\varphi \frac{A}{x} |, \frac{A}{x} \varphi$ and $\sigma^o \frac{A}{x} |, \frac{B}{x} \sigma^o$. Primary sexual state.

Female gametes before or after fertilization are $\varphi \frac{A}{x} |, \frac{A}{x} \sigma^o$.

Both partial and complete sex-reversal easily brought about, carpellate to staminate and staminate to carpellate.

On the basis of the cytological conditions and of the physiological theory of the nature of sex, the various possibilities of transmission and expression of the more common types of heredity in relation to sex are considered below. This is not to be regarded as an exhaustive analysis, however.

In relation to allosome-linked heredity and sex limitation we can have the following specific conditions:

1. Only the females are affected both by a single dose and by a double dose. Various types of hologynic heredity.
2. Only the males are ever affected both by a single dose and by a double dose. The various types of holoandric heredity.

3. Only the females (unpaired allosome condition) are ever affected, the heredity needed for the effect coming from the male. Dia-andric heredity.
4. Only the males (unpaired allosome condition) are ever affected, the heredity needed for the effect coming from the female. Diagynic heredity.
5. Both males and females are affected by a single dose, the heredity coming from either parent as a carrier. Ordinary dominant heredity and criss-cross heredity of the allosome condition in the chicken.
6. The females (homomorphic allosomes) affected only by a double dose, the males (heteromorphic allosomes) affected by a single dose. Daltonism, etc.
7. The males (homomorphic allosomes affected only by a double dose, the females (heteromorphic allosomes) affected by a single dose. The opposite of Daltonism. It should be possible in the Abraxas and chicken types of allosome constitution.
8. The females (heteromorphic allosomes) not affected, the males (homomorphic allosomes) affected by a double dose only. One type of holoandric heredity.
9. The males (heteromorphic allosomes) not affected, the females (homomorphic allosomes) affected by a double dose only. One type of hologynic heredity.

Since sex is developed in the cell or in the individual in various degrees of intensity and persistency, a low condition of maleness or femaleness may not inhibit or only partially inhibit in specific instances a given heredity so that exceptions to the statements may appear.

Now considering the various possibilities under each of the seven types of chromosome constitutions tabulated above, a definite program can be laid out by which any given case of hereditary transmission and its sex-limitations can be studied and defined.

I. HUMAN AND DROSOPHILA TYPE.

The type of chromosome constitution in which the female is homomorphic and the male heteromorphic for the allosomes "A" and "B", well established by cytological evidence (Painter 20, Stevens 29), may give rise to the following conditions, if A has a sex-influenced factor "*k*" and B has a sex-influenced factor "*l*."

1. A may have a factor *k* latent in the cell in the presence of the male state and in the presence of B.
2. A may have a factor *k* active in the cell in the presence of the male state and in the presence of B.

3. B may have a factor l latent in the cell in the presence of the male state and in the presence of A. The factor could only appear in case of sex reversal or abnormal allosome or chromosome associations.
4. B may have a factor l active in the cell in the presence of the male state and in the presence of A.
5. A may have a factor k latent in a single dose in the presence of the female state when associated with an allosome A without the factor.
6. A may have a factor k which is active even in a single dose in the presence of the female state when associated with an allosome A without the factor; and of course then also active in double dose.
7. A may have a factor k which is active only in a double dose in the presence of the female state.
8. A may have a factor k which is latent even in double dose in the presence of the female state.

Abnormal cases are produced by ordinary sex-reversal or by abnormal sex-determination because of the presence of supernumerary autosomes or allosomes in the cell, among which are the following:

9. B may have a factor 1 which may become active in the presence of a female state, although it shows no activity when the cell is in the normal male condition.
10. A alone, with a factor k might show activity of the factor when B is absent and in the presence of the male state.
11. A alone might have a factor k that is latent because of the absence of B and in the presence of the male state.

Ordinary Daltonism or red-green color blindness in man is apparently an example of cases "2", "5", and "7". Records have been established of 7 color blind women who had between them 17 sons, all color blind.

A certain type of senile cataract as reported by Enriques (6) is apparently an example of cases "1", and "6".

Schofield's (27) pedigree of webbed toes in man is apparently an example of case "4," or of "2" and "8".

The terms diagynic, dia-andric, hologynic, and holoandric heredity as used by Enriques (6) would be convenient but they are apparently too limited in their scope for general use to cover all the different types of hereditary transmission and expression and will need to be extended, either by modifying phrases or otherwise, when all the modes of allosome-linked and autosome-linked heredity and the relation of the factors to sex-limitation are known.

In the human type of allosome constitution, namely ♀ AA, AB ♂ :

1. If B has a factor l , active in the presence of the male state, it can only be transmitted from male to male. If B has a factor l , latent in the male state, it will be transmitted directly from male to male but will never show except possibly in case of sex-reversal.
2. If A has a factor k which is active only in double doses in the presence of femaleness and not active in the presence of the male state, then none of the offspring of an affected female will have the character unless the unaffected male parent is a carrier in which case all the daughters will be affected and the sons will, of course, be carriers.
3. If A has a factor k active in the presence of the male state it can not be transmitted to the sons directly but only from a mother.
4. If A has a factor k active in the presence of the male state but only active in double dose in the presence of the female state then it can only be transmitted directly to the male from an affected or unaffected female, in the latter case only half the sons showing the character; but to produce an affected daughter the father must be affected and the mother either affected or a carrier, in the latter case half the daughters being affected. In specific instances affected male offspring may be appearing from the line and possibly affected females for a long time, until a female carrying the factor is mated with an affected male.
5. If A has a factor k latent in the presence of the male state and B, but active in single dose in the presence of the female state associated with another A without the factor, and active also in double dose, then the character must be confined entirely to the female line and will appear in all the daughters if the mother has a double dose or if the father alone is a carrier. If the mother alone has the character and the heredity in single dose, half the daughters will be affected and half the sons will be carriers.
6. If A has a factor k which is latent even in double dose in the presence of the female state but active in the presence of the male condition, then the character will be confined to the male line but is transmitted to the sons only through the unaffected mother.

Any hypothesis as to which allosome has the heredity potentiality in any specific case can be tested out to a certain extent by breeding experiments, especially if sex reversal occurs sporadically or can be produced experimentally.

In man and *Drosophila*, etc. the allosomes are homomorphic in the female and heteromorphic in the male according to the scheme of A and B as outlined above. But in certain animals like *Abraxas* apparently, the male has the homomorphic set and the female the heteromorphic. According to Guyer's (8 and 9) cytological studies, the male somatic cells of the common chicken show two allosomes while the female somatic cells show only one of these bodies. In this case then, as indicated the allosomes are all of the type A and the female

contains an unpaired A. In spermatogenesis the two allosomes seem to pair and pass undivided to one pole, which would thus result in two spermatozoa each with an allosome and two without allosomes. The eggs presumably are formed half with an allosome and half without. Now to obtain the proper somatic condition, three possible things may happen: 1st., the spermatozoa without allosomes may not develop properly or, if they develop, fail to develop the primary sexual state completely; 2nd., the sperms may all develop properly but the eggs lacking the allosome may fail of normal development; or 3rd., all the eggs and sperms may develop properly but there is a lack of specific compatibility or an indifference between the eggs and spermatozoa without allosomes, or if these can conjugate the resulting zygote may be unable to develop. It is supposed, because of the results of the measurements of the spermatozoa, that the first assumption is the most probable.

We can assume that in the higher plants and the higher animals also, if the sexual state is determined in the gametes it is always determined in the egg, namely the sex which is continued in the developing individual; for apparently the sperm is too extremely differentiated into a male cell to pass over into the female state without passing through a seemingly impossible de-differentiation. Only in the very lowest sexual plants, like *Spirogyra*, for example, is it possible that a male gamete can pass over into the female state and this is actually known to occur occasionally. On the other hand it is well known that in the higher plants even a sister cell of the egg may pass to the minus or male state and conjugate with it. Occasionally sperms of some of the higher green algae have evolved to the condition in which they may pass back to a vegetative development as in certain species of *Oedogonium*, but in such cases a dwarf male is always the result.

When the eggs are homomorphic and the sperms heteromorphic, with AA ♀ and AB ♂ allosome sets, as in man, we can make three hypotheses as to sex-determination:

1. The haploid eggs having the same heredity and the same chromosome complement, the sex is determined by some physiological balance the same as in all cases of sex-determination in heterosporous, bisporangiate, diploid sporophytes; in haploid, hermaphroditic gametophytes in diploid hermaphroditic gametophytes; and in diploid, hermaphroditic animals; as well as in all cases of sex-reversal in diploid, monosporangiate sporophytes; in haploid, unisexual gametophytes; or in diploid unisexual animals or plants, whether allosomes are present in their cells or not.

Following this determination of the physiological gradient in the direction of one sexual state or the other there is a differential specific attraction with the more compatible kind of sperm, the egg determined toward maleness attracting the sperm with the allosome B, with its peculiar hereditary constitution, and the egg determined toward femaleness attracting the sperm with the allosome A. In this case the sex would actually be determined while fertilization is taking place, but it may also be normally completely determined before coming in contact with the sperm, but this does not mean that the sexual state is completely developed any more than that a new born child has its cells in a completely sexual, male or female state.

Not only do we know of the compatibility and incompatibility of the gametes of the same and of dissimilar species but in the synapsis of the chromosomes there is evident a very decided compatibility of synaptic mates and apparently a very decided incompatibility of chromosomes which are not mates. Moreover the differential parasitic growths of pollentubes is well known, which results in decidedly disturbed Mendelian ratios.

2. All the eggs may be in the same physiological condition at the time of fertilization, and attraction and union may take place purely by the law of chance and after fertilization the presence of the given type of allosome will produce a metabolic level that will throw the fertilized egg invariably toward the one sex, that with the allosomes AA toward femaleness and that with the allosomes AB toward maleness. There is nothing incompatible in this hypothesis with the physiological theory of sex. The sex is determined in exactly the same way as when determined or reversed in the vegetative tissues of the body, the special allosome merely giving the proper physiological state under the normal conditions. The allosomes are *merely sex-producing* having a direct effect on the physiology of the protoplast. The main difficulty with the hypothesis is that if the allosomes are thus sex-producing, the sexual state should remain unchanged so long as the bodies are present, which is plainly not the case in the great number of examples in which both secondary and primary sexual states are reversed in the individual. As stated, we have no objection to any one holding this second hypothesis provided he can give a convincing explanation as to why allosomes are specific and invariable sex-producers immediately after fertilization, before any specific sex is established, but cannot hold the sex after the soma is developed and a given sexual state thoroughly established.

3. There is not only random mating but the allosomes are Mendelian sex determiners in the same way as the autosomes determine the ordinary Mendelian characters, the female being homozygous and the male heterozygous for sex or vice versa. The allosomes are real "sex chromosomes". This third hypothesis is, however, so contradictory to the mass of known facts in relation to sexuality, so monstrous a misfit as an explanation of maleness and femaleness as it appeared and evolved in both the plant and animal kingdoms, that the wonder is that it could ever have been taken seriously as a scientific explanation of the facts of sexuality that have so far been amassed.

When the eggs have similar allosomes, therefore, the sex, either male or female, is determined by a physiological balance the same as in organisms without allosomes as for example in monecious species and in various diecious plants like the hemp where allosomes are apparently lacking. Now this balance may be conceived of as a certain point in the metabolic gradient of the cell or tissue involved. If the metabolism falls to one side the condition leads on to femaleness, if to the other to maleness for the given species. In some diecious plants, as in *Arisaema triphyllum*, the sexual state may not be developed in the egg at all but at a later stage and the physiological balance appears to be such that probably the sex is at first always thrown to maleness, although this is not yet entirely certain. The writer found a strong tendency toward maleness in young offshoots, no difference whether the parent corm was for the time being producing staminate or carpellate shoots.

In cases where the eggs have the heteromorphic allosomes, or where part of the eggs have an allosome and part have none we may consider that the sexual states arise in the same fundamental way as in other cases, but that the egg without the allosome or with the B type of allosome is thrown to femaleness while the A-containing egg is thrown to maleness. In this case no selective mating could arise and no incompatibility in relation to allosomes, unless the given egg under certain conditions, produced no reaction whatever in the sperms in which case individuals of only one sex would be produced at the time, for under the allosome conditions considered the sperms would all be alike. If any one objects with the proposition that the egg with the allosome should be thrown to femaleness and the one without to maleness, then we can only direct them to the condition in the flowers of the Anthophyta where the determinate floral axis always passes to the male state first and then to the female state near the end of the determinate growth; and also to a certain type of monecious inflorescence, the axis of which always develops the female state first with carpellate flowers and later the male state with staminate flowers, toward the end of the determinate growth when theoretically we might expect the opposite to take place. But as intimated above, in chickens the sperms without allosomes may develop and the eggs without allosomes may fail to function, in which case all the eggs would have the same type of allosome and a balance could be established through a physiological gradient.

In birds and similar cases therefore, the sex is determined in the egg apparently according to the allosome constitution, the allosome determining the physiological state. The egg without the allosome is determined as female that with the allosome as male. This is contrary to the usual assumption that the greater quantity of chromatin determines femaleness. But on the physiological basis of sex determination, the allosome associated with the male condition either single, as in the unfertilized egg, or double, as in the individual, may have factors which depress the nutrient level, so the absence of the allosome with the absence of these physiological factors would tend to produce femaleness. After fertilization the male has two of the A. allosomes and the female one A. It is, therefore, only a matter of degree or intensity of influence and we would then expect that the female could be changed to a male or the male to a female condition without great difficulty as is actually done by experiment at the present time.

Although the quantitative theory of sex, as developed by Goldschmidt, comes much nearer to the facts of sex determination and expression than the homozygous-heterozygous Mendelian hypothesis, which has up to the present been so blindly and enthusiastically accepted; it will be evident to any one familiar with the fact of experimentally induced sex reversals and re-reversals in unisexual individuals, as accomplished by the writer, as well as from a host of other phenomena, that any balance of genes imagined cannot be an explanation of sex determination and sexual dimorphism, since the change from one sex condition to the other and then back again is brought about during vegetative growth by ecological means, without disturbing, by aggregation or segregation, any balance of genes that might be present.

II. ABRAXAS TYPE.

The allosome formula is apparently ♀ AB, AA ♂. In general the conditions of activity and latency in relation to sex will be just the opposite from those in the human type.

1. A may have a factor k latent in the cells in the presence of the female state and in the presence of B.
2. A may have a factor k active in the presence of the female state and in the presence of B.

3. B may have a factor l latent in the cell in the presence of the female state and in the presence of A. This could never appear in character except in cases of sex reversal.
4. B may have a factor l active in the cell in the presence of the female state and in the presence of A.
5. A may have a factor k latent in a single dose in the presence of the male state when associated with an allosome A without the factor.
6. A may have a factor k which is active even in single dose in the presence of the male state when associated with an allosome A without the factor, and of course then also active in double dose.
7. A may have a factor k which is active only in a double dose in the presence of the male state.
8. A may have a factor k which is latent even in double dose in the presence of the male state.

Irregularities in allosome and chromosome distributions and sex reversals may, of course, occur as in the ♀ AA, AB ♂ type and produce unusual results in relation to sex limitation.

In *Abraxas* the grossulariata color as contrasted with the lacticolor is evidently a case of "2" and "6". The characters are not at all sex-limited or "sex-linked" but appear in either sex according to the ordinary Mendelian expectation limited, however, by the particular mode of migration of the allosomes. They are characters expressed by allosome-linked factors.

In the *Abraxas* type the heredity in relation to the allosomes may be transmitted as follows:

1. If B has a factor l active in the presence of the female state, it can only be transmitted from female to female. If B has a factor l latent in the female state, it could never show normally except in case of sex reversal.
2. If A has a factor k which is active only in double dose in the presence of maleness and not active in the presence of the female state then none of the offspring of an affected male will have the character unless the unaffected female parent has the factor also in which case the male offspring will be affected and the female offspring will become carriers.
3. If A has a factor k active in the presence of the female state and in the presence of B it cannot be transmitted to the daughters directly but only from a father.
4. If A has a factor k active in the presence of the female state but only active in double dose in the presence of maleness then it can only be transmitted directly to the female from an affected or unaffected male.
5. If A has a factor k latent in the presence of the female state and of B but active in single dose in the presence of the male state and another A without the factor and active also in double dose in the presence of the male state, the character will be confined entirely to the male line.

6. If A has a factor k which is latent even in double dose in the presence of the male state but active in the presence of the female state then the character will be confined to the female line but is transmitted to the female offspring only through the unaffected male parents.

III. CHICKEN TYPE.

The allosome formula is apparently ♀ Ao, AA ♂, the cells of the normal female having a single allosome.

1. A may have a factor k latent in the cell in single dose in the presence of the male state.
2. A may have a factor k active in the cell in single dose in the presence of the male state and, of course, also in double dose.
3. A may have a factor k active only in double dose in the presence of the male state.
4. A may have a factor k latent even in double dose in the presence of the male state.
5. A may have a factor k latent in single dose in the presence of the female state.
6. A may have a factor k active in single dose in the presence of the female state.

When sex-reversal takes place, which is comparatively frequent in the case of the hen, latent factors in the allosome as well as sex-limited factors in the autosomes may become active. Chickens apparently furnish favorable material for the study of allosome-linked and sex-limited heredity.

Any factor in A active in the female state can be derived only from the male parent directly, so until the normal heredity is established in a cross, great care must be taken else a desirable factor may be lost. Taking into account the allosome formula, the migration of the allosomes and the condition of any factors which the allosomes contain the hereditary transmission can easily be worked out.

Taking the well-known case of the golden Sebright and silver Sebright bantam chickens and assuming again that the eggs are heteromorphic and the sperms homomorphic in respect to allosomes because of the failure of the allosome-lacking spermatids to develop properly, then we can explain the breeding results (see Punnett 21) as follows:

Suppose that "silver" is dominant and "golden" recessive and that these factors are in the allosomes A, and suppose that the eggs with allosome A are determined as males and the eggs without allosome A are determined as females. Then crossing

golden Sebright ♀ with silver Sebright ♂ will give only silver females and only silver males; for both types of eggs will get an allosome A containing the factor S.

Silver Sebright ♀ crossed with golden Sebright ♂ will give golden females and silver males, because the females will get an allosome with factor g (golden) and have no silver while the males would have an allosome with golden and also one with the dominant silver.

The F₂ from the F₁ of the first cross will give both silver and golden females but only silver males; for the eggs will be half without and half with the A allosome containing the factor for silver and the sperms will be half with allosome A containing the factor for golden and half with allosome A containing the factor for silver which will thus always give a male with at least one dose of silver.

The F₂ from the F₁ of the second cross will give both silver and golden females and both silver and golden males; for the eggs will be without the allosome or else have the allosome A containing the factor for golden and the sperms will have either the allosome A with the factor for golden or the allosome A with the factor for the dominant silver. So the allosome-lacking egg can receive either allosome A (g) or allosome A (s) and the other type of egg will have only the allosome A (g) which on conjugating with one or the other type of sperms will produce a zygote homozygous for golden and the other heterozygous for the dominant silver.

The characters are, therefore, not at all sex-limited nor "sex-linked" but are in plain language non-sex-limited characters whose factors are allosome-linked.

The familiar example of the cross between non-barred Cornish Indian Game chickens and Barred Plymouth Rocks is of the same nature as well as various other sets of allelomorphic characters whose potentialities presumably are in the allosome A.

IV. SPHAEROCARPUS TYPE.

Since the sporophyte is homosporous no sexual dimorphism is possible in it but hereditary factors in allosome A or in allosome B may be active and if this is the case characteristic hereditary transmissions would appear. The gametophytes having the haploid complement of chromosomes and each kind of allosome being constantly associated with one sex, any

allosome-linked factors could only produce characters in the one sex unless sex-reversal takes place. Any sex-limited character or any character not sex-limited whose factors are in the allosomes would show a 1 to 1 ratio. Any factor in allosome A would give a character constantly associated with femaleness and any factor in allosome B would give a character constantly associated with maleness. In case of a heterozygous condition of a sex-limited factor in the autosome any gametophytic character will appear in half the males or in half the females as the case may be.

V. *EQUISETUM ARVENSE* TYPE.

The sporophyte is homosporous and can normally have no sexual dimorphism. There are no allosomes but the haploid gametophytes are determined in the spores or in the early stages of germination as female and male individuals with ordinary sex-limited characters. Both gametophytes can be reversed and the newly developed parts will then show the opposite sex-limitation. Factors which are heterozygous in the sporophyte will show equal segregation and will show equal ratios in the two sexes; while any such heterozygous factors that give rise to sex-limited characters in the gametophytes will also show in half the individuals of the sex involved.

VI. *CANNABIS SATIVA* TYPE.

No allosomes being present in the dioecious hemp, the sex is determined in the eggs of like hereditary constitution either before or after fertilization and the potentialities of the sex-limited sporophytic characters, which are numerous, are all in ordinary chromosomes. In case of sex-reversal all the sex-limited characters of the opposite sex that can be developed in the reversed parts appear. No heredity or condition of any kind is known to influence the sex of the gametophytes although the sporocytes may undergo sex-reversal. The haploid complement of chromosomes will show male sex-limited characters in the pollen grains no difference what the hereditary complex may be, after male determination in the sporophyte; and the same complement of chromosomes will show female sex-limited characters in the female gametophytes after female determination in the sporophyte. The sex is not affected by the reduction division. Whether any specific factors give rise

to sex-limited characters in both gametophyte and sporophyte is not known. Since sex-reversal is easily accomplished, characters latent and normally never appearing in the sex present will show in the reversed branches and thus reveal the presence of heredity in the given individual which could otherwise only be inferred.

VII. HUMULUS TYPE.

Any allosome-linked heredity and sex-limitation in general will be expressed in the same way in the sporophyte as in Man and *Drosophila*. The sex of the gametophytes has no relation to the allosome distribution but follows that which was present in the flowers which produced the spores from which the gametophytes originate. Abundant sex reversal is produced in the sporophyte, the male to the female and the female to the male, by means of a short daily illumination period. The carpellate plant with the homomorphic set of allosomes possesses all the factors or potentialities of both sexes the same as the staminate plant with the heteromorphic set of allosomes. The homozygous-heterozygous sex formula is thus a figment of the imagination.

THE FIVE GENERAL TYPES OF HEREDITARY EXPRESSION.

The five general types of hereditary expression as influenced either by primary or secondary sexual states may then be summarized as follows:

1. The peculiarity of inheritance produced by dominance and recessiveness through which an individual shows characters transmitted directly from one parent only, which characters have no relation to the special sex of the individual or any part of the individual under the influence of a sexual state, their factors being influenced only by the ordinary physiological conditions or gradients which cause them to be active or latent for the time being. These are the ordinary Mendelian heredities often observed to be handed down from father to daughter or from mother to son, or vice versa in either case. The factors are autosome-linked or, in case there are no allosomes, merely chromosome-linked, and the characters are not sex-limited.

2. Sex-limited or sex-influenced heredity, the factors being autosome-linked and expressing characters either through direct influence or through latency or activity brought about by the presence of one sexual state or the other. These are the ordinary sex-limited characters producing sexual dimorphism either between entire individuals or different parts or cells of the same individual.

3. Hereditary characters whose factors are in the allosomes, on account of which they receive a distinctive distribution in transmission not sex-limited or sex-influenced in nature however.

4. Hereditary characters which have their factors in the allosomes and are sex-limited in single dose through the action of one sexual state or the other.

5. Hereditary characters which have their factors in the allosomes and which are sex-limited in double dose through the influence of one sexual state or the other.

IMPORTANT LITERATURE CONSIDERED.

1. ALLEN, C. E. A Chromosome Difference Correlated with Sex Difference in *Sphaerocarpos*. Science N. S. 46:466, 467. 1917.
2. ALLEN, C. E. An Apparently Sex-linked Sporophytic Character in *Sphaerocarpos* Anat. Rec. 26:388, 389. 1923.
3. BLACKBURN, KATHLEEN B. The Cytological Aspects of the Determination of Sex in the Dioecious Forms of *Lychnis*. British Jour. Exp. Biol. 1:413-430. 1924.
4. DONCASTER, L. On Sex Inheritance in the Moth *Abraxas grossulariata* and its var. *lacticolor*. Rep. Evol. Committee 4:53-57. 1908.
5. EMERSON, R. A. A Genetic View of Sex Expression in the Flowering Plants. Science 59:176-182. 1924.
6. ENRIQUES, PAOLO. Hologynic Heredity. Genetics 7:583-589. 1922.
7. GOLDSCHMIDT, RICHARD. Intersexualitaet und Geschlechtsbestimmung. Biolog. Zentralb. 39:498-542. 1919..
8. GUYER, MICHAEL F. The Spermatogeneses of the Domestic Guinea (*Numida melagris dom.*) Anat. Anzeiger 34:502-513. 1909.
9. GUYER, MICHAEL F. Studies on the Chromosomes of the Common Fowl as Seen in Testes and Embryos. Biol. Bull. 31:221-268. 1916.
10. HARRISON, J. W. HESLOP. Sex in the *Salicaceæ* and its Modification by Eriophyid Mites and other Influences. British Jour. Exp. Biol. 1:445-472. 1924.
11. JANSSENS F. A. La Theorie de la Chiasmotypie. La Cellule 25:389-411. 1909.
12. MCCLUNG, C. E. A Peculiar New Element in the Male Reproductive Cells of Insects. Zool. Bull. 2:187-197 1899.
13. MCCLUNG, C. E. The Accessory Chromosome—Sex Determinant? Biol. Bull. 3:43-87. 1902.
14. MCPHEE, HUGH C. Meiotic Cytokinesis of *Cannabis*. Bot. Gaz. 78:335-341. 1924.
15. MONTGOMERY, T. H. Are Particular Chromosomes Sex Determiners? Biol. Bull. 19:1-17. 1910.
16. MORGAN, T. H. An Attempt to Analyze the Constitution of the Chromosome on the Basis of Sex-limited Inheritance in *Drosophila*. Jour. Exp. Zool. 11:365-411 1911.
17. MORGAN, T. H. and BRIDGES, C. B. Sex-linked Inheritance in *Drosophila*. Carnegie Institution of Washington, Publication No. 237:1-87. 1916.
18. MORGAN T. H. STURTEVANT, A. H. MULLER, H. J. and BRIDGES, C. B. The Mechanism of Mendelian Heredity. Revised edition. 1922. Chap. IV pp. 78-140; Chap. VII. pp. 187-201.
19. MOTTIER, D. M. The Development of the Heterotypic Chromosomes in Pollen Mother-cells. Ann. Bot. 21:309-347. 1907.
20. PAINTER, THEOPHILUS S. Studies in Mammalian Spermatogenesis. II. The Spermatogenesis of Man. Jour. Exp. Zool. 37:291-321. 1923.

21. PUNNETT, R. C. Heredity in Poultry. Chapter IV. pp. 50-59. 1923.
22. SCHAFFNER, JOHN H. The Expression of Sexual Dimorphism in Heterosporous Sporophytes. Ohio Jour. Sci. 18:101-125. 1918.
23. SCHAFFNER, JOHN H. Influence of Environment on Sexual Expression in Hemp. Bot. Gaz. 71:197-219. 1921.
24. SCHAFFNER, JOHN H. Control of the Sexual State in *Arisaema triphyllum* and *Arisaema dracontium*. Am. Jour. Bot. 9:72-78. 1922.
25. SCHAFFNER, JOHN H. Sex Reversal in the Japanese Hop. Bull. Torr. Bot. Club. 50:73-79. 1923.
26. SCHAFFNER, JOHN H. The Influence of Relative Length of Daylight on the Reversal of Sex in Hemp. Ecology 4:323-334. 1923.
27. SCHOFIELD, RICHARD. Inheritance of Webbed Toes. Jour. Heredity. 12:400-401. 1921.
28. SHARP, LESTER W. The Factorial Interpretation of Sex-determination. La Cellule 35:195-235. 1924.
29. STEVENS, N. M. A Study of the Germ Cells of Certain Diptera with Reference to the Heterochromosomes and the Phenomena of Synapsis. Jour. Exp. Zool. 5:359-374. 1908.
30. VALENTI, ANNA LOUISA. Sulla Determinazione del Sesso Nello Mosche. Bios. 2:265-298. 1913.
31. WINGE, O. On Sex Chromosomes, Sex Determination, and Preponderance of Females in Some Dioecious Plants. Compt. Rend. Carlsberg 15: 1-26. 1923.
32. WUIST, ELIZABETH DOROTHY. Sex and Development of the Gametophytes of *Onoclea struthiopteris*. Physiological Researches 1:93-132. 1913.
33. YAMPOLSKY, C. Inheritance of Sex in *Mercurialis annua*. Am. Jour. Bot. 6:410-442. 1919.
34. YAMPOLSKY, CECIL. Die Chromosomen in der maennlichen Pflanze von *Mercurialis annua*. Ber. Deutsch. Bot. Ges. 43:241-253. 1925.

THE ALIMENTARY CANAL OF THE MEXICAN BEAN BEETLE.

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INTRODUCTION.

The Mexican Bean Beetle, *Epilachna corrupta* Muls., is entirely a plant feeder, living usually on the leaves of garden and field beans. Its feeding habit differs in this respect from most other coccinellids, which (except for a few species), are predaceous on other insects.

Data concerning the economic importance, distribution, life history, habits, and control of the Mexican bean beetle have been published elsewhere by a number of writers, but no information concerning the internal anatomy was available. This work was undertaken because of the author's desire to become better acquainted with the internal structure.

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THE GROSS ANATOMY.

The alimentary canal is shown in Figure 1. It is a more or less simple tube running from the mouth to the anus. The canal has three, well-defined, primary divisions. These are the fore-intestine, mid-intestine and hind-intestine. The canal of the beetle is three times the length of the beetle, while the canal of the larva is nearly twice the length of the larva.

The fore-intestine is very short, extending back only as far as the first thoracic segment. It consists of a short pharynx, a short oesophagus, and a short, somewhat thin-walled crop. The oesophagus is slightly greater in diameter than the pharynx.

The mid-intestine or ventriculus is divided into what is known as the first and second divisions of the ventriculus. The first division runs from the first segment to the fifth segment in the form of a nearly straight tube of uniform diameter. At the fifth segment there is a slight constriction. From here the second division begins in the form of a tube one-third less in diameter than the first division, but twice the length of the first division. During its course it twice coils back on itself.

The hind-intestine, which is composed of three regions, starts at about the beginning of the eighth segment where it joins the mid-intestine slightly at an angle. The six malpighian vessels arise near

the point of union, and after a more or less lengthy course through the body cavity, they enter the large intestine at a point just behind where the ileum (first division) joins the colon (second division). The ileum is small, short and somewhat twisted.

The ileum attaches to the colon on the right side of the body at the beginning of the ninth segment. From this point the colon gradually enlarges as it bends back towards the meson, dorsad of the ileum. The diameter of the colon (including the peritoneal sheath that surrounds it) is nearly twice the diameter of the ileum and almost exactly twice the diameter of the rectum. The colon passes directly into the rectum (third division), which is only one short segment in length. The rectum is surrounded by well developed circular muscles, inside of which are eight epithelial folds bordered with intima which nearly fills the lumen. The excrement is always fluid-like and a large open passage would probably not be necessary.

Larva and Adult.

The histological nature of the digestive tract of the larva is very similar to that of the adult. The discussion given in this treatise is concerned with the adult. However, mention is made of the larva in places where the difference in the two is most noticeable.

THE HISTOLOGY OF THE ALIMENTARY CANAL.

THE FORE-INTESTINE.

Proportionately the pharynx is very short. The histological nature of the pharynx and oesophagus is almost identical in regards to the type of intima and epithelium. The epithelium is more simple and is not thrown into folds as is the case with the oesophagus. Epithelium cells of this region are slightly smaller and more irregular than in the oesophagus. The diameter of the oesophagus is only slightly greater than that of the pharynx while the diameter of the mid-gut is about three times as great as the diameter of the oesophagus. See Figure 5.

Intima of the oesophagus is only moderately well developed, and seems to be thrown into a series of longitudinal folds, usually four in number. The primary intima is very thin and stains slightly with eosin. The teeth are backward pointed and rather strong at the anterior end of this region, but disappear at the posterior end, and are here replaced by rather blunt projections and depressions in the folds of intima.

The epithelial cells of the oesophagus are small and irregular, and the cell divisions are not always clear. The nuclei stain rather dark. The cytoplasm is non-vascular, non-granular, and homogenous. A cross section through the oesophagus is shown in Figure 3.

The basement membrane is not clearly distinguishable in all the sections.

About fifteen longitudinal muscle fibers occur between the circular muscle layer and the basement membrane. They are inserted in the intima near the posterior end of the pharynx. From here they continue through the fore-intestine, the mid-intestine, and a part of the hind-intestine.

The longitudinal muscles of the fore-gut and circular muscles of the mid-gut lie snugly against the basement membrane, and are not very strongly developed except at the oesophageal valve.

The crop is not so well developed in *Epilachna corrupta*. See Figure 5, C.

The oesophageal valve, as in similar cases among insects, is a large fold of the fore-intestine, projecting into the mid-intestine, nearly closing the passage between them. Unlike the alder flea beetle (Woods, 1918) in this respect, the oesophageal valve of the bean beetle is rather large, with bulb-like folds, which are well developed. See Figures 4 and 5.

The intima is very thick towards the oesophagus, but becomes gradually thinner as one passes towards the mid-intestine, finally disappearing at a point immediately behind the top of the two folds which form the valve. The intima (chitin) on the folds has a somewhat bluntly-jagged or dull, toothed appearance.

The peritrophic membrane is secreted by the digestive epithelium on the posterior side of the oesophageal valve. This is a delicate structureless membrane, which is found in the lumen of the mid-intestine and the hind-intestine, lying between the food and the delicate epithelium. It protects the latter from injury from sharp food particles. Digestive juices secreted behind this membrane probably pass through it by osmosis.

A striated border in this region of the mid-intestine is seldom visible, and is never well developed.

The epithelial cells of the fore-gut in the anterior face of the oesophageal valve become cuboidal, then slightly more columnar, narrower, more elongate, and gradually change to the type more characteristic of the mid-gut.

On the posterior face of the oesophageal valve the cells are very long, narrow and crowded. They have small, oval nuclei which contain small, usually well separated chromatin granules. The layer of cells are arranged in such a way that they appear as being in more than one irregular layer, closely wedged together. The epithelium of the two oesophageal valve folds, particularly on the posterior side, stains rather dark. On the posterior face of the valve folds the cytoplasm granules are fine and dense.

The basement membrane is continuous from the fore-intestine to the mid-intestine.

The longitudinal muscle fibres are continuous from the fore-gut to the mid-gut. They are internal in the fore-gut and external in the mid-gut. The fibres evidently divide into two or three upon leaving the oesophageal valve since from a dozen to about fifteen medium-large fibres are found in the fore-gut, while from thirty-six to forty small fibres are observed in sections made through the mid-gut. All the fibres of the fore-intestine are larger than those of the mid-intestine.

THE MID-INTESTINE.

First Division of the Ventriculus.

A striated border is not clearly distinguishable in the anterior region of this division in *Epilachna corrupta*, but a rather thin striated

border is found towards the posterior end of this region. This condition is possibly due to the glandular nature of the cells in this vicinity and will be discussed later. The striæ are close together and not always clearly separated from the cytoplasm anteriorly.

The epithelium is of the columnar type and the cells are well defined. The cells of the anterior part of this region are long and medium wide, but may vary some in the same insect. In the anterior part of this same region, immediately behind the oesophageal valve, are found six to eight deep pits or annular folds, and it is from these pits that most of the secretion in this region comes. These annular pits or pouches may extend entirely around the intestine, and are found throughout the first one-third of the first division of the ventriculus, and can be seen in dissection. The epithelium of the posterior end of this division is not replaced by typical nests, but instead has embryonic cells scattered along the basement membrane at the base of the epithelium. The same conditions occurs in the larva. The nuclei are rather large, round, and usually medium in position except when the cell contents are being discharged. The cells are about four to five times as high as they are wide, depending upon their physiological condition. Cells at the anterior end of this division are much higher than those near the posterior end. In the resting state the cytoplasm becomes charged with vacuoles, which pass to the outer margin of the cells. A very thin basement membrane is present. See Figures 5 and 6.

Small, thin, striated circular muscle fibres surround the mid-intestine. The fibres are branched. They usually appear as one delicate muscular layer. This layer is outside the longitudinal muscles in the fore-gut and inside the longitudinal muscles in the mid-gut. Approximately thirty-six longitudinal branched muscle fibres lie outside the circular muscle layer. They become smaller towards the posterior end of the mid-gut.

The Second Division of the Ventriculus.

The striated border is not very well developed in this region. It shows more clearly at the posterior end of the first division of the ventriculus, but apparently it continues throughout the mid-gut with different degrees of development. The striæ do not seem to be clearly separated from the cytoplasm in this portion of the ventriculus. See Figures 9 and 10.

The epithelial cells are much longer and narrower than those of the first region. Often they nearly fill the lumen. They are not equal and straight as in the case with the posterior end of the first mid-gut division. The free ends of these cells are irregular to oval in shape. The secretions are more active here than in the preceding region. The cytoplasmic balls are very granular and stain a light pink with cosin. See Figure 8.

Discharged cells are replaced from nidi or nests of embryonic cells which lie on the basement membrane. The number of nests in a single section is from fifteen to twenty-five. Usually each nest contains from three to twelve nuclei. Usually these nidi are inside the circular muscles. However, some sections indicate that under certain conditions some of the nests lie outside the muscle layer.

Immediately preceding the transition to the hind intestine, the cells of the mid-intestine become smaller, more numerous and irregular. Small nests or nidi also become more prevalent. At the extreme end of the mid-intestine the cells lose their columnar structure, the cell divisions become very indistinct, and the replacement cells are close together and abundant. See Figures 12 and 13.

The basement membrane is of the same nature as in the former division.

Both circular muscle fibers and longitudinal fibers are of the same nature as in the preceding region.

THE HIND-INTESTINE.

No typical pyloric valve occurs in the gut of *Epilachna corrupta*. However, immediately behind the malpighian vessels the lumen of the ileum is very small, the intima smooth, and the epithelium nearly equal and straight, instead of being irregular or thrown into folds. Epithelial cells at this point are small and cubical with indistinct walls. The nuclei stain very distinctly. There are several compact, thick, interlacing circular muscle layers surrounding and fitting closely against the basement membrane, around the entire circumference of the intestine. Figures 11 and 14 show this condition.

The Proximal Portion of the Ileum.

The striated border of the mid-intestine stops entirely with the end of the mid-intestinal epithelium, and is here replaced by a layer of intima. Immediately behind the pyloric valve (Figure 15) there occurs a very thin primary layer of fine hair-like or cilia-like intima. The secondary intima is also thin but is solid and much thicker than the primary intima.

The epithelial cells of the hind-gut are at first narrow, but become wider and higher, and shortly merge into an epithelium typical of the middle portion of the ileum. The cytoplasm is slightly vascular, very fibrillar, non-vesicular, and homogenous. The epithelium is thrown into six large wavy folds, and is composed of slightly triangular to oblong cells, which are higher than they are wide. They are smaller than those of the distal ileum and do not have clearly distinguishable cell walls. The nuclei are round, chromatic, and full of densely packed granules.

The proximal portion of the ileum discussed here is very short and extends not more than a hundred micra caudad of the pyloric valve. See Figure 15.

The basement membrane is thin but is always present, it is continuous from one region to another, and clearly defined.

There are about fifteen to twenty longitudinal muscles fibers, which lie among connective tissue between the basement membrane and the circular muscles. Posteriorly they are probably inserted on the intima towards the distal portion of the ileum. There are usually three layers of circular muscle fibers which lie outside the longitudinal fibers. These fibers are well developed and about twice as thick as the mid-intestinal fibers.

The Distal Portion of the Ileum.

In the distal portion of the ileum all layers present are continuous with those of the proximal ileum.

A very narrow, irregular, tooth-like intima borders the epithelium. This intima is very thin and only appears as one (or primary intima). It becomes gradually thinner throughout this region.

The epithelium of this region is composed of medium-sized, irregularly cuboidal cells, whose cell walls are very distinct. The nuclei are medium large and may be round or oval in outline. They contain large, distinct, chromatic granules, especially in the center. The epithelium is often thrown into acute folds, but this varies in the different specimens. The folds are typically six in number. A very thin clearly distinguishable basement membrane is present. See Figure 16.

The longitudinal muscle fibers are continuous anteriorly with those of the distal-mid-intestine and end a little before reaching this region. They begin at the anterior end of the pharynx, are internal in the fore-gut, external in the mid-gut, and internal in the hind-gut (ileum). They are internal in the proximal region and end before reaching the distal end of the ileum. Circular muscle fibers are well developed, and as elsewhere, are striated. They are continuous anteriorly with those of the proximal section of the ileum, and posteriorly with those of the colon.

The Colon.

At the transition point or union the canal bends caudad but at this point there is practically no difference between the epithelium of the ileum as compared with that of the colon. The intima, basement membrane, and circular muscles are continuous, while the longitudinal muscles of the ileum disappear entirely.

The intima is slightly thicker here than it was in the region just discussed, and a primary and secondary intima can be distinguished. In nearly all of the cases where the intima of the hind-gut is discussed by writers working on other Coleoptera, the intima is described by them as thicker than is in the case with the Mexican Bean Beetle. In this insect the primary intima appears only as a thin line. The secondary intima is clear and does not stain with eosin or with Delafield's haematoxylin.

In following the course of the colon towards the rectum the epithelial cells gradually become flatter and flatter. This change begins with the association of the malpighian vessels with the walls of the intestine. The epithelial cells of the distal portion of the colon are about one-third as high as those of the ileum, and are not quite as wide. The cytoplasm is of the same structure throughout, resembling very closely that of the preceding region. The nuclei are oval, and about the same size as those of the ileum, but the chromatic granules are slightly larger and fewer in number. Some of the cell divisions are clear, while some are not. Probably this is due to fixation. The epithelium is usually thrown into six acute folds which project into the lumen. See Figure 17. The basement membrane is always very thin and is not always distinct.

The circular layer of muscle fibers of the pyloric valve, ileum, and anterior part of the colon are well developed, but the fibers grow weaker and weaker as one traces them towards the rectum. They do not disappear, however, until the end of this region is reached. They are continuous with the circular muscles of the preceding region, where the most posterior muscle is inserted in the intima of the colon.

The Malpighian Vessels.

The malpighian vessels of the Mexican bean beetle are six in number, and constitute a single series, arising stysematically like six spokes on an axle. They begin at the junction of the mid-gut and the hind-gut and go anteriorly through the vicinity of the second division of the ventriculus (where they are very much coiled), and then closely appress the walls of the first division of the ventriculus as far as the crop (which is located in the prothorax). From this point they double back on themselves, and pass through the body cavity in close proximity to the intestine as far caudad as the rectum. At this point they again turn back on themselves until they reach the junction of the ileum and the colon, where three vessels enter the colon on each side very close together. They enter as six vessels, then divide, and re-divide, finally ramifying at the posterior end of the colon. A cross section made through the anterior end of the colon shows six small, circular vessels, while sections made through the posterior end of the colon may show as many as sixteen large irregularly shaped vessels.

The malpighian vessels are slightly larger along the vicinity of the ventriculus, but grow rather small a short distance before they enter the colon, and remain in this condition for a short distance after entering, then enlarge again towards the posterior end of this region. The vessels are of a thin, opaque-white color. See Figure 19.

The malpighian vessels in the body cavity are elliptical to circular in shape. They are covered interiorly by a lightly staining striated border. The striæ are pointed at the free ends, but wider at their bases. The cytoplasm stains a violet pink with eosin, is very granular, and presents a fibrillar aspect. The nucleus, which is proportionately large, varies in shape from elliptical to round, and is typically basal to central in position. The chromatic granules are large and usually well separated. There are four cells in a typical cross section. The malpighian cells of the free tubules have a distinct and well-developed basement membrane. There is no indication of a thin, delicate, irregular, lightly straining fibrillar area just inside the basement membrane as is the case with the cells of the distal portion of the tubules. A malpighian vessel, greatly enlarged, is shown in Figure 20.

The malpighian vessels are closely associated with the circular muscle layer of the colon. Their peritoneal sheaths grow out and join, so that a continuous nucleated peritoneal sheath is formed, which completely surrounds the colon enclosing the malpighian vessels. The vessels do not extend along the wall of the rectum, but instead they terminate blindly at the extreme posterior end of the large intestine. See Figure 17.

The Rectum.

The transition between the colon and the rectum is the most abrupt in the whole course of the alimentary canal. New circular muscles suddenly appear and the malpighian vessels and nucleated peritoneal sheath end abruptly. The epithelial cells of the colon become flatter and flatter, and the cell boundaries more and more distinct near the rectum; but this type changes very quickly to the glandular eosinophile cells, characteristic of the rectum. The rectum is very short and is only one-half the diameter of the colon.

There are at first more or less small, smooth, wavy folds in the intima and epithelium, but as one proceeds caudad these folds become more and more pronounced, and more tooth-like in shape, while the lumen becomes smaller. Probably the typical number of folds is six but as they are very irregular the number is often eight. The intima of this region is thicker, more jagged-like and more irregular than that of the colon. As expected, the primary and secondary intima are continuous with the primary and secondary cuticle of the body wall.

The cells of the epithelium are about one-half the size of those in the preceding region, but the cell divisions are not always clear. The epithelium cells are very thin, irregular in shape, and stretched out. At the bases of the folds, the cells are not clearly defined and often seem to be wanting. The cytoplasm is smooth and non-granular, while the nuclei are smaller than those of the ileum and colon, and are less chromatic. As one passes caudad, the epithelium becomes more and more glandular and continues out into the hypodermis of the body-wall. See Figure 18.

The basement membrane is continuous throughout the rectum as well as being continuous with the basement membrane of the body wall. In this region it is clear and well-defined.

There are several layers (usually three) of circular muscles that go around the rectum. They are striated and well-developed. These muscles are inserted on the cuticula around the proctodeal invagination. Each layer is attached independently of the other layers. There are no longitudinal muscles in the rectum of the Mexican bean beetle, neither internally nor externally.

LITERATURE CONSULTED.

- DUFOR, LEON. 1823-1825. *Ann de sci. nat. ser. L t. 2:462-482; pl. 20-21; ser. 1, t. 3:215-242, 476-491, pl. 10-11, 13-15, 29-31; ser. 1, t. 4: pl. 5-8.*
 1840. *Ann de sci. nat. ser. 2, t. 14: 225-240, pl. 11.*
 1842. *Ann. de sci. nat. ser. 2, t. 18: 162-181, pl. 4-5.*
 1843. *Ann. de sci. nat. ser. 2, t. 19: 145-182, pl. 6-9.*
 NEEDHAM, J. A. *Zool. Bull., Boston, Vol. 1, 1897.*
 FOLSOM AND WELLS. *Univ. Studies (Illinois) Vol. II, No. 2, 1906.*
 PAYARKOFF, ERASTE (1910). *Arch d ant. micro t. 12: 333-474, text, fig. 1-69.*
 JORDAN, H. *Biol. Centralbl. Bd. 30, 1910.*
 GORKA, ALEXANDER VON. 1914. *Zool. Jahr. Abt. f. Zool. Bd. 34, 233-338, pl. 10-11.*
 WOODS, WM. COLCORD. *Annals of Ent. Soc. of America, Vol. IX, p. 391-408, 1916.*
Annals of Ent. Soc. of America, Vol. XXV, p. 283-319, 1918.

EXPLANATION OF THE PLATES.

All figures of adult except Fig. 7.

PLATE I.

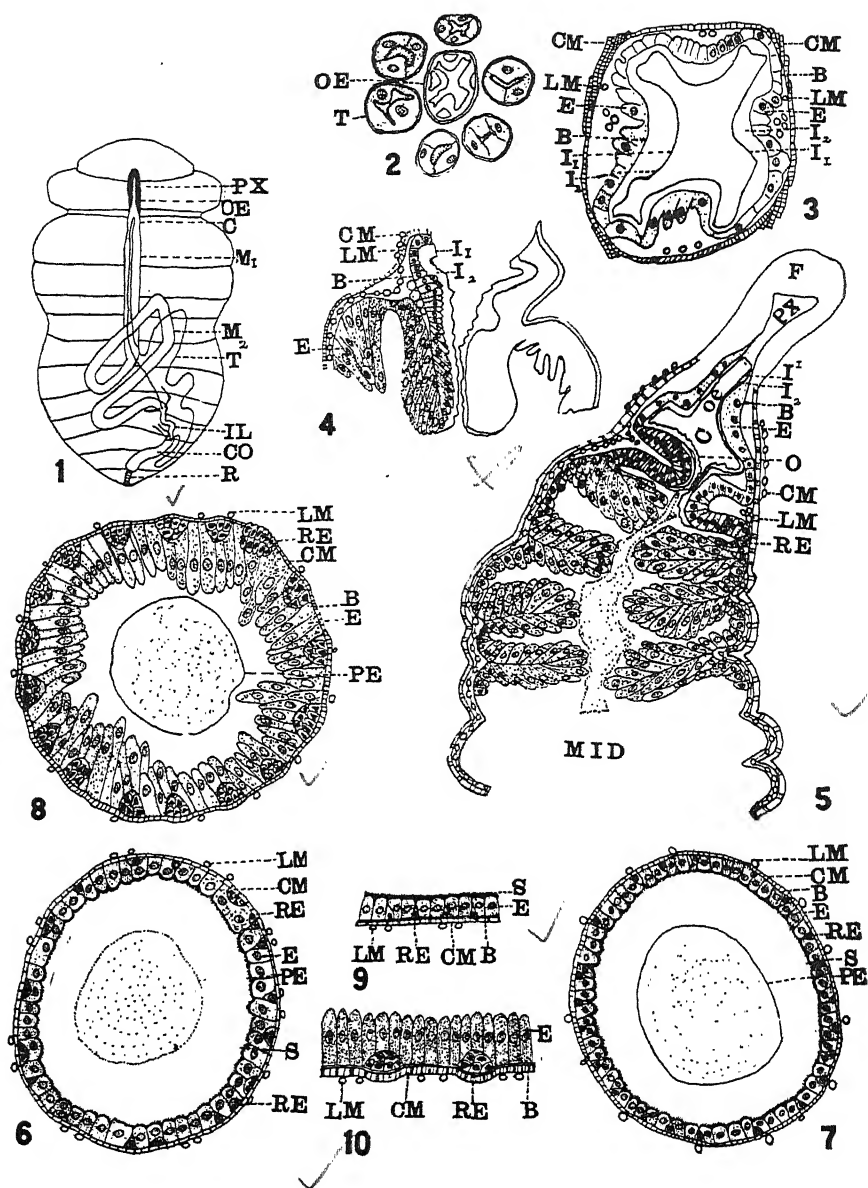
- Fig. 1. The alimentary canal and malpighian tubules in the adult beetle.
 Fig. 2. Cross section through the oesophagus to show its relation to the malpighian tubules.
 Fig. 3. The oesophagus, cross section.
 Fig. 4. The oesophageal valve, longitudinal section.
 Fig. 5. The pharynx, oesophagus, crop, oesophageal valve, and the anterior portion of the first division of the mid-intestine (ventriculus), longitudinal section.
 Fig. 6. The posterior portion of the first division of the ventriculus of the adult, cross section.
 Fig. 7. The posterior portion of the first division of the ventriculus of the larva, cross section. Compare difference in replacement cells with Fig. 6.
 Fig. 8. The second division of the ventriculus, cross section.
 Fig. 9. The posterior portion of the first division of the ventriculus, cross section.

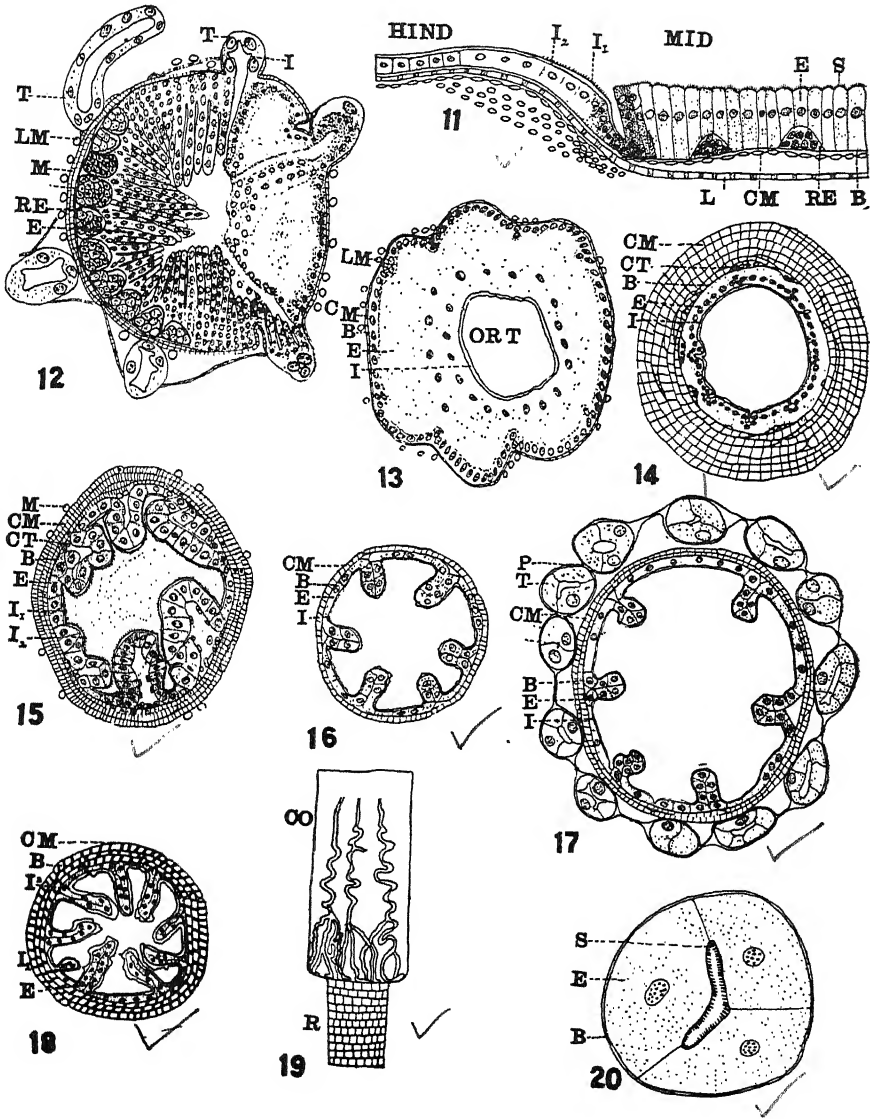
PLATE II.

- Fig. 10. The second division of the ventriculus, cross section.
 Fig. 11. The transition from the ventriculus to the ileum, longitudinal section.
 Fig. 12. A cross section, made slightly at an angle, through the invagination of the malpighian tubules showing ventriculus epithelium on the left and the ileum epithelium on the right.
 Fig. 13. The origin of the malpighian tubules, cross section made a few micra behind Fig. 12.
 Fig. 14. Cross section through the ileum near the transition immediately behind Fig. 13.
 Fig. 15. The posterior portion of the ileum taken a few micra behind Fig. 14, cross section.
 Fig. 16. The central and posterior ileum, cross section.
 Fig. 17. The colon; a cross section, showing the peritoneal sheath and malpighian tubules in their relation to the colon.
 Fig. 18. The rectum, a cross section.
 Fig. 19. Diagram showing the ramification of the malpighian vessels in the wall of the colon.
 Fig. 20. A malpighian tubule greatly enlarged.

ABBREVIATIONS USED IN THE FIGURES.

- | | |
|-------------------------------------|------------------------------------|
| B—Basement Membrane. | CM—Circular Muscles. |
| C—Crop. | CT—Connective Tissue. |
| CO—Colon. | F—Fore-Intestine. |
| E—Epithelium. | IL—Ileum. |
| HI—Hind-Intestine. | I—Primary Intima. |
| LM—Longitudinal Muscle. | I2—Secondary Intima. |
| MID—Mid-Intestine. | M—Muscle. |
| M2—Mid-Intestine (second division). | M1—Mid-Intestine (First division). |
| OE—Oesophagus. | O—Oesophageal Valve. |
| ORT—Origin Mal Tubules. | P—Peritoneum. |
| Pe—Peritrophic Membrane. | PX—Pharynx. |
| R—Rectum. | RE—Replacement Cells. |
| S—Striated Border. | T—Malpighian tubules. |





A PHAENOLOGICAL NOTE ON THE FLORA
OF THE VICINITY OF COLD
SPRING HARBOR, N. Y.*

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In recent years interest in phaenological studies has been stimulated by the work of Sir Francis Darwin. In the first of these studies of his on the British Flora, Darwin¹ could not correlate the first flowering of 231 species of these plants with the temperature factor. His observations in this case extended over the years 1917-18-19, and for the months of January to July inclusive of those years. In his next paper² he states, however, that the early flowering of the species in the years 1918 and 1920 must be connected with the relatively higher temperatures ruling in the spring of those two years. This paper gave observations upon 272 species over the period January to September during the years 1919-20. In a third paper,³ Darwin remarks that it was not surprising for the flowering dates to be early in 1921, since the temperature had been above normal that year. Commenting upon his results from 233 species over the period November 1920 to September 1921, he observes that the rainfall during the period considered had been the smallest of the past 105 years in the British Isles. He remarks, "the connection of low rainfall with early flowering is probably to be ascribed partly to the quicker warming up of the dryer soil in the spring so that early growth would be promoted through the higher soil temperature, provided sufficient water is present for the needs of growth. In regard to early flowering as such it is well known that individual plants

*Paper on program of the Ecological Society of America, Washington meeting, 1924.

¹1919. Darwin, Sir Francis. A Phaenological Study. *New Phytologist* 18:287-298.

²1921. *Ibid.* Studies on Phaenology, No. 2, 1920. *New Phytologist* 20:30-38.

³1922. *Ibid.* Studies on Phaenology, No. 3, 1921. *New Phytologist* 21:34-40.

growing in spots where the supply of water is soon exhausted produce a smaller bulk of vegetation and flower correspondingly earlier though of course less profusely than those growing in spots where water is available for a longer period."

Lyon¹ studied floral and meteorological records of the Hanover, N. H. district for the years 1917-21 inclusive. For the first and last years he was able to very definitely associate a cool temperature with late flowering while the remaining years also gave evidence in favor of the factor of temperature control on the flowering of plants. He made no attempt, however, to correlate these periods with the amount of precipitation which had occurred.

The records upon which our observations are based were made at the Biological Laboratory, Cold Spring Harbor, N. Y. in the summers of 1922-23-24 during the six weeks period in which the Laboratory was in session, between the last week of June and the second week in August. Many of the plants which bloom during the summer in that region may flower in the spring months, so for the purposes of accuracy we include in our observations only those species listed in Britton and Brown or Gray as blooming from June onward (Table I). Since in other cases our records were for only two of the three years considered, we have been forced to use as the basis of our tentative conclusions a comparatively small number of species—44 in all. In comparison, the number of species considered by Darwin over the same period in three years were 59, 51 and 50. The meteorological records used are those of the United States Weather Bureau Station at Roslyn, L. I., (Table II), which is comparatively near Cold Spring Harbor. While our results indicate that for each of these three years the majority of the flowers appeared in the weeks of July 8, 14 and 20, certain differences in the sequence apparently confirm the findings of Darwin and Lyon.

1922. If we compare the totals of the first four and the last three weeks of the observation period of this year with similar periods in 1923, we observe that certain species flowered later in 1922 than 1923. This was also the case in a number of other species not included in the list, because we obtained no records for them in 1924. It will be noticed from the accompanying table that 1922 was not nearly so warm as 1923 during the flowering period which fact brings out a slight correlation of

¹1922. Lyon, C. J. A Phaenological Study in New England. *Torreyana* 22:19-28.

time of flowering with the temperature. Although the temperatures of 1922 were largely above normal from January on, a greater number of subnormal temperatures as well as a

TABLE I.

Species	Earliest Date. Month Day†	June 27	July					August		
			8	14	20	26	1	7	13	
1. Hemerocallis fulva.....	6-28	0	x*	...	...	...	...	...	...	...
2. Lysimachia terrestris...	6-28	x	0	*	...	...	...	...	...	...
3. Rubus odoratus.....	6-30	x	*	0	...	...	...	...	...	...
4. Leonurus Cardiaca.....	7-2	.....	0	*	...	x	...	...	...	...
5. Spartina glabra.....	7-2	.....	0 x	...	...	*	...	...	...	...
6. Spartina patens.....	7-2	.....	0 x	*	...	...	...	...	...	...
7. Verbascum Thapsus....	7-3	0 *	x	...	...	...	...	...	...	...
8. Agrimonia gryposepala..	7-4	.....	x	* 0	...	...	...	...	...	...
9. Agrostis alba.....	7-4	.....	* 0	x	...	...	...	...	...	...
10. Arctium minus.....	7-4	.....	*	...	...	x 0	...	...	...	...
11. Asclepius syriaca.....	7-4	.....	* 0 x	...	...	...	...	...	...	...
12. Chrysopsis falcata.....	7-4	.....	0 x	...	*	...	...	...	...	...
13. Hypericum perforatum..	7-4	.....	x 0	...	*	...	...	...	...	...
14. Lathyrus maritimus....	7-4	.....	* 0	x	...	...	...	...	...	...
15. Melilotus alba.....	7-4	.....	* 0 x	...	...	...	...	...	...	...
16. Plantago maritima....	7-4	.....	0	*	x	...	...	...	...	...
17. Rumex crispus.....	7-4	.....	* 0	...	x	...	...	...	...	...
18. Helianthus annuus.....	7-5	.....	x	0	*	...	...	...	...	...
19. Limonium carolinianum.	7-5	.....	x *	0	...	...	...	...	...	...
20. Typha angustifolia.....	7-5	.....	x	*	...	0	...	...	...	...
21. Verbascum Blattaria....	7-5	.....	0 *	x	...	...	...	...	...	...
22. Chimaphila maculata...	7-6	.....	x	0	*	...	...	...	...	...
23. Circaea lutetiana.....	7-6	.....	x	0	*	...	...	...	...	...
24. Ligustrum vulgare.....	7-6	.....	0	*	x	...	...	...	...	...
25. Sericocarpus asteroides.	7-6	.....	x	0	*	...	...	...	...	...
26. Linaria Cymbalaria.....	7-8	.....	*	0	x	...	...	...	...	...
27. Clethra alnifolia.....	7-9	.....	0	...	x	*	...	...	...	...
28. Nepeta Cataria.....	7-9	.....	0	x	*	...	...	...	...	...
29. Calluna vulgaris.....	7-10	.....	*	...	0 x	...	...	...	...	...
30. Impatiens biflora.....	7-10	.....	*	x	0	...	...	...	...	...
31. Cephalanthus occidentalis.....	7-11	.....	...	x	0	...	...	...	*	...
32. Sericocarpus linifolius...	7-11	.....	...	x	* 0	...	...	...	...	...
33. Polygala polygama....	7-11	.....	...	x 0	*	...	...	...	...	...
34. Amaranthus retroflexus.	7-12	.....	...	0	...	...	x	...	*	...
35. Chenopodium album.....	7-12	.....	...	0 x	...	...	...	...	...	...
36. Oenothera muricata....	7-12	.....	*	*	0 x	...	...	...	...	...
37. Verbena urticaefolia....	7-12	.....	...	x 0	...	*	...	...	...	...
38. Mollugo verticillata....	7-14	.....	...	x	*	0	...	...	...	...
39. Epipactis pubescens....	7-15	.....	...	x	...	*	...	...	0	...
40. Centaurea Cyanus.....	7-17	.....	...	...	0	...	x	...	*	...
41. Epilobium angustifolium	7-17	.....	...	0	*	x	...	...	...	...
42. Hypopitys americana....	7-17	.....	...	x	* 0	...	...	...	...	...
43. Apocynum cannabinum..	7-21	.....	...	...	0 *	x	...	...	...	...
44. Lobelia cardinalis.....	7-23	.....	...	...	0	x	*	...	...	...

† -x = 1922.

0 = 1923.

* = 1924.

TABLE II.
Roslyn, N. Y.

WEEK OR MONTH	NORMAL DAILY MEAN TEMPERATURE	DEVIATION FROM NORMAL DAILY MEAN TEMPERATURE		
		1922	1923	1924
	(1914-1924)			
January.....	29.48	— .69	+ .17	+1.11
February.....	28.88	+4.32	—3.48	—1.88
March.....	37.80	+3.30	—1.80	—1.40
April.....	48.19	+1.41	— .21	—1.90
May.....	58.50	+4.20	+ .30	—4.10
Total.....	.....	+12.54	—5.02	—8.17
	(1922, 1923, 1924)			
June 1-26.....	68.5	+ .9	+3.3	—4.2
June 27-July 8.....	69.7	+1.8	—1.0	— .9
July 9-14.....	72.5	— .4	+ .5	— .1
July 15-20.....	72.6	+ .9	+2.6	—2.5
July 21-26.....	72.7	— .8	+ .1	+ .6
July 27-August 1.....	70.0	— .3	+ .1	+ .2
August 2-7.....	73.5	—2.0	+2.6	— .8
Total.....	.....	+ .1	+8.3	—8.5

Roslyn, N. Y.

WEEK OR MONTH	NORMAL DAILY MEAN PRECIPITATION	DEVIATION FROM NORMAL DAILY MEAN PRECIPITATION		
		1922	1923	1924
	(1914-1924)			
January.....	4.23	—2.00	+3.28	+ .13
February.....	3.76	— .07	— .85	+ .40
March.....	3.22	+1.11	+1.02	—1.47
April.....	3.72	+ .26	— .72	+2.69
May.....	3.78	+ .45	—1.93	+1.79
Total.....	.....	— .25	+ .80	+3.54
	(1922, 1923, 1924)			
June 1-26.....	.19	+ .07	— .01	— .07
June 27-July 8.....	.15	+ .17	— .06	— .10
July 9-14.....	.15	— .11	— .15	— .06
July 15-20.....	.08	+ .09	— .03	— .07
July 21-26.....	.09	— .07	— .01	— .09
July 27-August 1.....	.08	+ .03	+ .03	— .07
August 2-7.....	.11	+ .12	— .06	— .07
Total.....	.....	+ .30	— .29	— .53

greater amount of precipitation occurred during the flowering season. In view of Darwin's suggestion that a low rainfall is usually associated with earlier flowering through a more rapid warming up of the soil, it seems plausible that the temperature in this case were insufficient under the conditions to have such an effect. Apparently then for this year, the low temperature abundant precipitation during the growing season together and the delayed the time of flowering with the evidence favoring the precipitation as the factor tending to nullify the accumulative effects of the higher temperatures of the preceding months.

1923. Study of the records for this year by the method previously described indicates that the majority of the flowers in this year bloomed earlier than those of 1922 and 1924. During the summer of 1923 there occurred the highest temperatures of the growing seasons of the three years considered; hence we have a positive correlation with the temperature factor. The precipitation during the growing season of this year is seen to be less than that of 1922. Since the season was neither as dry nor as cold as that of 1924, we should expect earlier flowering to characterize the year. The temperatures for this year were mostly above normal from January on, while the precipitation was above normal during the first five months only. If the number of cases really supplies sufficient evidence, this correlation checks quite well with Darwin's observation that not only higher temperatures but lower rainfall also are connected with earlier flowering.

1924. A very clear tendency toward late flowering is shown in this year through comparison of the totals of the last four weeks of the three years and this is correlated with predominantly lower temperatures. But the late flowering is correlated with lower precipitation during the flowering period. If lower rainfall is usually associated with earlier flowering through rapid warming up of the soil, this apparently contradictory instance may be explained by the fact that the temperature of the 1924 season was too low to have the usual effect in warming up the soil. Apparently then, the temperature was a stronger determinant of the time of flowering for this year than the precipitation.

In conclusion, then, it is evident that the time of flowering is determined by the prevailing temperature; this, in turn, is modified by the amount of precipitation during the growing season.

DESCRIPTIONS OF FIFTEEN NEW SPECIES OF CERATOCAPSUS (HEMIPTERA, MIRIDÆ).*

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The writer has published a key in the "Hemiptera of Connecticut" (1923) to the species of *Ceratocapsus* known from the northeastern United States. Since then considerable material from the south and southwestern states has been studied with the result that several new species have been recognized. The writer is preparing a key in which it is hoped to include all the known North American species, and later to publish with figures of the male genitalia for each species. However, pressure from various students for determinations of species has made it necessary to publish descriptions and make the names available at the earliest possible moment, with the result that the present paper is offered now.

Ceratocapsus taxodii new species.

Allied to *luteus* Kngt., and runs in the couplet with that species in my key (Hem. Conn., 1923, p. 525), but is distinguished by length of antennal segment II which is slightly greater than width of vertex plus dorsal width of an eye, also by the smaller size and reddish coloration, and yellow antennæ having segment IV reddish.

♂. Length 3.2 mm., width 1.3 mm. Head: width .77 mm., vertex .26 mm. Rostrum, length 1.17 mm., reaching to middle of hind coxæ. Antennæ: segment I, length .27 mm.; II, .86 mm.; III, .51 mm.; IV, .51 mm.; all segments nearly equal in thickness, yellow, segment IV reddish. Pronotum: length .60 mm., width at base 1.08 mm.; impunctate, alutaceous like the hemelytra. General body form very similar to *luteus*; coloration nearly uniformly reddish, in dark specimens becoming dark reddish due to a slight infuscation of the chitin; legs and antennæ uniformly yellowish except segment IV which is reddish. Pubescence very similar to that of *luteus*, although the simple pubescence somewhat more prominent. Membrane uniformly pale fuscous, becoming gradually paler toward base. Genitalia distinctive, form near that of *luteus* but the right clasper with apical third decurved and flattened at apex to a chisel-like edge.

*Contribution from the Department of Zoology and Entomology, Iowa State College, Ames, Iowa.

♀. Length 3.1 mm., width 1.3 mm. Head Width .68 mm., vertex .31 mm. Antennæ: segment I, length .27 mm.; II, .86 mm.; III, .51 mm.; IV, .51 mm. Pronotum: length .60 mm., width at base 1.08 mm. Very similar to the male in pubescence and coloration.

Holotype: ♂, June 16, 1927, Colycell, Louisiana (H. H. Knight); author's collection.

Allotype: Same data as the type.

Paratypes: 14 ♂ ♀, taken with the types on cypress (*Taxodium distichum*). FLORIDA—♂ ♀, June 1, Sanford; 10 ♂ ♀, July 23, 1926, Jacksonville, (E. D. Ball). ILLINOIS—♂, June 28, 1909, Pulaski (C. A. Hart), in cypress swamp. LOUISIANA—12 ♂ ♀, June 15, Bogalousa; ♂, June 15, Covington; 2 ♂ 2 ♀, June 18, 1917, Shriever (H. H. Knight). MISSISSIPPI—6 ♂ ♀, July 24, Columbus; ♂ 2 ♀, July 15, Durant; ♀, July 23, Natchez; ♂ 2 ♀, July 22, Port Gibson; 2 ♀, June 18, Vicksburg (C. J. Drake). TENNESSEE—18 ♂ ♀, July 16, 1919, Walnut log (W. L. McAtee), on cypress.

Ceratopsus bifurcus new species.

Allied to *lutescens* Reut., and very similar in coloration, but differs in the more prominent, bristly pubescence, vertex broadly but distinctly concave, and by the very distinct genital claspers.

♂. Length 4.1 mm., width 1.8 mm. Head: width .91 mm., vertex .30 mm.; eyes more prominent above than in *lutescens*, being emphasized by the shallowly concave vertex. Rostrum, length 1.43 mm., attaining hind margins of intermediate coxæ. Antennæ: segment I, length .37 mm.; II, 1.28 mm.; III, .63 mm.; IV, missing. Pronotum: length .74 mm., width at base 1.4 mm.

Coloration nearly identical with *lutescens*; uniformly pale yellowish, head and two lines above base of coxal cleft bright red. Genital claspers distinctive; left clasper with basal, dorsally projecting process, bifurcate on apical half and curving distad, the dorsal prong more slender and curving inward. Right clasper very different from *lutescens* and *rubricornis*, being more nearly the form of *modestus* Uhl., but the apical half decurved, thick, and ending in an abrupt sharp point.

♀. Length 4 mm., width 1.9 mm. Head: width .86 mm., vertex .37 mm. Antennæ: segment I, length .37 mm.; II, 1.33 mm.; III, .60 mm.; IV, .56 mm. Pronotum: length .78 mm., width at base 1.46 mm. Similar to the male in coloration and pubescence.

Holotype: ♂, April 2, 1921, Miami, Florida (D. M. DeLong); author's collection.

Allotype: May 5, 1926, Cocoa, Florida (E. D. Ball); author's collection.

Paratype: ♀, June 14, 1921, Miami, Florida (D. M. DeLong). ♀, April 20, 1912, Marco, Florida (W. T. Davis). 2♂ 1♀, July 23, 1926, Jacksonville (E. D. Ball).

Ceratocapsus rubricornis new species.

Allied to *lutescens* Reut., and very similar in coloration, but distinguished by the genital claspers and the uniformly red antennae.

♂. Length 4.3 mm., width 1.7 mm. Head: width .87 mm., vertex .31 mm. Rostrum, length 1.4 mm., reaching upon base of hind coxae. Antennae: segment I, length .47 mm.; II, 1.5 mm., equal in thickness to segment I, although more slender basally; III, .77 mm.; IV, .70 mm.; deep red, last two segments somewhat darker red. Pronotum: length .86 mm., width at base 1.4 mm.; relatively longer than in *lutescens*.

Coloration and pubescence nearly as in *lutescens*, but differs in the uniformly red antennae; uniformly yellowish, head, propleura above middle of coxal cleft, and hind tibiae, bright red. Genital claspers distinctive; differs from *lutescens* by the long decurved, sickle-shaped apical half of right clasper, and the broader basal spine.

♀. Length 4.4 mm., width 1.9 mm. Head: width .81 mm., vertex .37 mm. Antennae: segment I, length .47 mm.; II, 1.63 mm.; III, broken. Pronotum: length .80 mm., width at base 1.43 mm. Coloration and pubescence similar to the male.

Holotype: ♂, June 22, 1921, Agricultural College, Mississippi (C. J. Drake); author's collection.

Allotype: Same date as the type.

Paratype: ♂, taken with the type.

Ceratocapsus divaricatus new species.

This species runs to *incisus* Kngt. in my key (Hem. Conn., 1923, p. 525), but differs in the sparsely set, erect long hairs on hemelytra, in the larger and more prominent eyes, and the more strongly infuscated membrane.

♂. Length 3.3 mm., width 1.2 mm. Head: width .78 mm., vertex .25 mm. Rostrum, length 1.03 mm., scarcely attaining posterior margins of intermediate coxae. Antennae: segment I, length .23 mm., brown, a red annulus at base; II, .73 mm., gradually thickened from base toward apex where it attains the thickness of segment I, dark fuscous brown, more reddish brown at apex; III, .41 mm., scarcely attaining the thickness of segment II, brownish black; IV, missing. Pronotum: length .68 mm., width at base 1.19 mm.; finely punctate.

Brownish black to piceous, clavus and base of corium brown; coxae apically, bases of femora, apices of tibiae except hind pair, and tarsi, more or less pale. Membrane dark fuscous, bordering the cuneus and

more or less behind anal vein, pale with a tinge of brown. Dorsum finely punctate; rather thickly clothed with silvery, fine scale-like pubescence, and intermixed with sparsely set, erect, long brownish hairs, the arrangement very similar to that of *scelosus* Reuter. Genitalia very distinctive, right clasper with a distal acuminate process (length .185 mm.), also with an incurved sickle-shaped arm arising from the thick base. Left clasper with an erect basal process, terminating in a point turned at right angles, the apical arm makes a right angle turn dorsally, producing a vertical process which terminates above in a broad spear-shaped point set at a right angle; the points on the two arms of the clasper point in opposite directions like the hands on the upraised arms of an Egyptian dancer, but the left hand or point is much larger than the other.

Holotype: ♂, May 15, 1926, Sanford, Florida (E. D. Ball); author's collection.

Ceratocapsus balli new species.

Allied to *divaricatus*, and is distinguished most easily by the differently formed male genitalia; pronotal disk impunctate. Runs to *sericus* Kngt. in my key (Hem. Conn., 1923, p. 525) but is distinguished by the shorter antennal segments, smaller and more slender form, and by the piceous and more strongly shining aspect.

♂. Length 3.4 mm., width 1.17 mm. Head: width .74 mm., vertex .257 mm. Rostrum, length 1 mm., reaching to middle of intermediate coxæ. Antennæ: segment I, length .24 mm.; II, .85 mm.; III, .46 mm.; IV, .40 mm. Pronotum: length .60 mm., width at base 1.13 mm.; disk impunctate, strongly shining, clothed with rather long simple pubescence. Hemelytra with pubescence and punctuation nearly as in *divaricatus*; apical half of corium and cuneus piceous, strongly shining. Membrane and veins pale with yellowish tinge, dark fuscous on apical half, or behind a transverse line formed by apices of areoles.

Genital claspers distinctive, although indicating a close relationship with *divaricatus*; right clasper forming a rather long, curved, U-shaped structure, the internal arm more slender, the apex bent or hooked. Left clasper with basal prong short, acuminate, suberect, the apical arm, somewhat curved, non-angulate, the apex broad and flat, forming a point at each side of the flattened apical area.

♀. Length 2.9 mm., width 1.2 mm. Head: width .66 mm., vertex .30 mm. Antennæ: segment I, length .23 mm.; II, .76 mm.; III, .44 mm.; IV, .40 mm. Pronotum: length .57 mm., width at base 1.1 mm. Coloration, pubescence, and punctuation, very similar to that of the male.

Holotype: ♂, May 15, 1926, Sanford, Florida (E. D. Ball); author's collection.

Allotype: Same data as the type.

Paratypes: ♂, May 5; ♂, May 9, 1918, Gainesville, Florida (C. J. Drake). 3 ♀, June 1, 1926, Sanford, Florida (E. D. Ball), collected on live oak.

Ceratopsus uniformis new species.

This species runs to *incisus* Kngt., in my key (Hem. Conn., 1923, p. 525), but differs in the shorter antennal segment III, which is not equal to width of vertex plus dorsal width of an eye, in the shorter and more ovate form, uniformly dark brown color, fuscous membrane, and the differently formed genital claspers.

♂. Length 3 mm., width 1.5 mm. Head: width .70 mm., vertex .27 mm. Rostrum, length 1 mm., reaching upon middle of hind coxæ. Antennæ: segment I, length .23 mm.; II, .80 mm.; III, .43 mm.; IV, .37 mm.; yellowish, segment IV brownish, and segment I with red mark at base as in *rufistigmus*. Pronotum: length .60 mm., width at base 1.26 mm.

Dorsum more sparsely clothed with yellowish simple pubescence than in *pumilus* Uhler, and intermixed with fine scale-like pubescence; punctuation slightly stronger and more distinct. Coloration uniformly dark reddish brown, darker on anterior half of pronotum and somewhat paler on basal margin. Membrane uniformly fuscous brown. Legs yellowish, hind femora more brownish on apical half. Genital structures very suggestive of *pumilus*, but differs in the much smaller and margined tubercle above base of left clasper; the middle prong of left clasper lying flat against the large apical prong; the middle prong of the right clasper flat and blade-like.

♀. Length 3 mm., width 1.5 mm. Head: width .70 mm., vertex .31 mm. Antennæ: segment I, length .23 mm.; II, .86 mm.; III, .43 mm.; IV, .37 mm. Pronotum: length .60 mm., width at base 1.28 mm. Similar to the male in punctuation, pubescence, and coloration.

Holotype: ♂, July 18, 1915, Springfield, Missouri (H. H. Knight); author's collection.

Allotype: July 22, 1915, Hollister, Missouri (H. H. Knight).

Paratypes: DISTRICT OF COLUMBIA—♂ ♀, July 30, Aug. 18, 1907; Washington (W. L. McAtee). ILLINOIS—♂, July 20, 1909, Fountain Bluff. MARYLAND—♀, Aug. 14, Beltsville; ♂, July 12, Odenton; ♀, July 19, ♀, Aug. 2, 1914, Plummers Island (W. L. McAtee); ♀, July 9, 1905, Marshall Hall (J. G. Sanders). MISSISSIPPI—♀, July 24, Columbus; ♀, July 9, 1921, Corinth (C. J. Drake). VIRGINIA—6 ♀, July 27, 1898, Paris (O. Heidemann); ♂, Aug. 1, 1915, Mount Vernon (W. L. McAtee). WEST VIRGINIA—2 ♀, Aug. 20, 1891, Berkeley (O. Heidemann).

Ceratocapsus quadrispiculus new species.

Allied to *uniformis* and very similar in size and coloration, but differs in the strongly arcuate embolar margins and very distinct genital characters; rostrum somewhat shorter, membrane uniformly dusky, legs uniformly yellowish.

♂. Length 2.9 mm., width 1.5 mm. Head: width .68 mm., vertex .31 mm. Rostrum, length 1.04 mm., not attaining hind margins of middle coxæ. Antennæ: segment I, length .24 mm.; II, .81 mm.; III, .42 mm.; IV, .32 mm.; yellowish, segment IV reddish, segment I, with red mark near base. Pronotum: length .58 mm., width at base 1.2 mm.

Coloration very similar to *uniformis* but the dorsum more densely clothed with pubescence. Membrane uniformly dusky, paler than in *uniformis*. Legs yellowish. Genital structures distinctive; left clasper with four prongs, the middle pair having a common base, curving upward and U-shaped; right clasper with basal prong short, flat, the broad apex curving slightly upward to a point, the apical prong recurved above, rather broad and flattened at apex, and nearly reaching base of clasper, also having a short, curved subapical prong.

Holotype: ♂, June 16, 1917, Colyell, Louisiana (H. H. Knight); author's collection.

Paratypes: 2 ♂, taken with the type. ♂, July 23, 1922, Glen Echo, Maryland (J. R. Malloch).

Ceratocapsus complicatus new species.

Suggestive of *pumilus* Uhler, but having long erect simple pubescence on the dorsum as in *setuosus* Reut., runs to *pumilus* in my key (Hem. Conn., 1923, p. 525) but distinguished at once by the long erect pubescence; usually two fuscous spots are visible on pronotal disk, one behind each callus.

♂. Length 3.8 mm., width 1.5 mm. Head: width .77 mm., vertex .257 mm. Rostrum, length 1.16 mm., just attaining hind margins of middle coxæ. Antennæ: segment I, length .27 mm., yellowish, with red mark near base; II, 1 mm., yellowish; III, .57 mm., reddish brown; IV, .47 mm., dark reddish. Pronotum: length .68 mm., width at base 1.26 mm.

Coloration and punctuation nearly as in *pumilus*, but pubescence nearly as in *setosus*. Genital structures very distinctive; right clasper with basal fork directed downward where it divides into two sickle-shaped blades which recurve inwardly, the dorsal half of clasper with a pair of shorter, U-shaped prongs above, the posterior fork twice as long as the other; left clasper shaped like the tail of a fish apically, with a short spine above near base; the chitinous terminal portion of the aedeagus divided into a pair of ventrally curved blades.

Holotype: ♂, July 22, 1915, Hollister, Missouri (H. H. Knight); author's collection.

Paratypes: ♂, May 19, July 4, 1918, Gainesville, Florida (C. J. Drake). ♂, July 24, 1921, Columbus, Mississippi (C. J. Drake). 2♂, Aug. 9, 1913, Plum Point; ♂, Aug. 14, 1914, Beltsville, Maryland (W. L. McAtee).

Ceratopsus fuscognatus new species.

Suggestive of *punctulatus* Reuter described from Texas, but differs in the shorter pubescence, shorter antennal segments, and the setigerous punctures of the dorsum not infuscated.

♂. Length 2.7 mm., width .97 mm. Head: width .67 mm., vertex .214 mm. Rostrum, length 1.03 mm., extending upon middle of hind coxæ. Antennæ: segment I, length .26 mm.; II, .91 mm., not equal to one and a half times width of head; III, .63 mm., nearly equal to width of head; IV, .38 mm.; yellowish, last segment dusky. Pronotum length .44 mm., width at base .88 mm.

Dorsum more finely and closely punctate than in *punctulatus* but the punctures not infuscated. Clothed with fine golden yellow simple pubescence and intermixed with fine scale-like silvery pubescence, the whole interspersed with a series of erect, longer golden yellow hairs, much as in *setosus* Reut., but shorter than those on *punctulatus*. Coloration rather uniformly yellowish, cuneus and sometimes the corium tinged with reddish, scutellum and inner apical angles of corium usually infuscated, hind tibiæ and head sometimes becoming infuscated. Membrane fuscous, pale within areoles and bordering apex of cuneus. Genital claspers distinctive, the right clasper with claw-like hook above base while the apical process terminates in a hook of equal size and form.

♀. Length 2.6 mm., width 1.03 mm. Head: width .61 mm., vertex .28 mm. Antennæ: segment I, length .21 mm.; II, .86 mm.; III, .60 mm.; IV, .40 mm. Pronotum: length .44 mm., width at base .83 mm.; III, .60 mm.; IV, .40 mm. Very similar to the male in punctuation, pubescence and coloration.

♀. Brachypterous form. Length 2.2 mm., width 1 mm. Head: width .64 mm., vertex .28 mm. Rostrum, length 1.14 mm., extending behind posterior coxæ or to base of ovipositor. Antennæ: segment I, length .26 mm.; II, .88 mm.; III, .56 mm.; IV, .46 mm. Pronotum: length .43 mm., width at base .76 mm. Hemelytra rounded at apex, cuneal fracture distinct, membrane reduced to a narrow margin bordering inner side of cuneus, last segment of abdomen and tip of ovipositor exposed above. Punctuation, pubescence, and coloration similar to the macropterous form.

Holotype: ♂, October, 1925, Tampa, Florida (E. D. Ball); author's collection.

Allotype: Same data as the type.

Paratypes: ALABAMA—36 ♂ ♀, September 5 and 6, Eufaula; ♀, September 8, 1926, Clanton, at light (H. H. Knight). ARIZONA—3 ♀, July 20, 1917, Texas Pass; ♀, July 22, 1917,

Tucson (H. H. Knight). ARKANSAS—♂, September 10, 1926, Newark, at light (H. H. Knight). FLORIDA—♂ ♀, May 3, 1916, Cocoa; ♀, May 15, 1926, ♂, August 25, 1925, Sanford (E. D. Ball); ♂, April 16, 1914, Orlando (G. G. Ainslie). IOWA—♂, May 8, 1926, Ames (H. H. Knight), collected at light. NEW MEXICO—♂, July 12, 1917, Deming (H. H. Knight), at light. TEXAS—3 ♀, August 30, Brownwood; ♂, June 26, Gillette; 3 ♂, June 23, Richmond; 2 ♂, July 2, Sabinal; 2 ♂ 1 ♀, June 25, 1917, Victoria (H. H. Knight).

Morphotype: ♀, August 25, 1925, Sanford, Florida (E. D. Ball); author's collection.

Paramorphotypes: ♀, July 12, 1917, Tucson, Arizona (H. H. Knight). 3 ♀, May 5, 1926, Cocoa, Florida (E. D. Ball); ♀, July 1, 1917, Helotes, Texas (H. H. Knight).

Ceratopsus barbatus new species.

Runs to *modestus* Uhler in my key (Hem. Conn., 1923, p. 525), but is distinguished by the more prominent and thickly set, suberect pubescence, the eyes also distinctly pubescent.

♂. Length 4.2 mm., width 1.8 mm. Head: width .86 mm., vertex .32 mm.; eyes and head clothed with prominent erect pubescence. Rostrum, length 1.5 mm., reaching to middle of hind coxæ. Antennæ: segment I, length .38 mm.; II, 1.33 mm., somewhat more slender than segment I; III, .59 mm., equal to thickness of segment II; IV, .50 mm., equal to thickness of segment III; uniformly dark brown, clothed with prominent pubescence. Pronotum: length .80 mm., width at base 1.42 mm.; impunctate.

Clothed with prominent, erect or suberect, simple brown pubescence. Coloration uniformly dark brown, the pronotum and scutellum darker brown, sometimes nearly piceous, apex of scutellum reddish; antennæ and legs usually of a lighter shade of brown. Genital claspers distinctive although closely related to *modestus* Uhler; apical half of left clasper with the two arms widely divergent.

♀. Length 4.4 mm., width 1.8 mm. Head: width .83 mm., vertex .38 mm. Antennæ: segment I, length .37 mm.; II, 1.33 mm.; III, .56 mm.; IV, .44 mm. Pronotum: length .80 mm., width at base 1.45 mm. Pubescence and coloration similar to the male.

Holotype: ♂, July 11, 1926, Vienna, Virginia (H. H. Knight); author's collection.

Allotype: Same data as the type.

Paratypes: 2 ♂, taken with the types on *Pinus virginiana* to which tree the species appears to be confined in its breeding habits. DISTRICT OF COLUMBIA—16 ♂ ♀, June 24, ♂, July 16, 1897; ♀, July 12; ♂, July 25, 1909, Washington (O. Heide-

mann). MARYLAND—2 ♂ ♀, July 20, 1892, Bladensburg (O. Heidemann). ♂ ♀, June 14, 1914; ♀, August 8, 1915, Beltsville; ♂ 3 ♀, July 25, 1914, Great Falls; ♀, June 17, 1913, Plummers Island (W. L. McAtee), on *Pinus virginiana*. ♀, July 17; ♂, July 25, 1926, Glen Echo (H. H. Knight), on *Pinus virginiana*.

Ceratocapsus mcateei new species.

Runs to *lutescens* Reut. in my key (Hem. Conn., 1923, p. 525), but differs in the small size, brownish head and pronotum, and by the red hind femora and cuneus; clothed with fine, short, simple pubescence.

♀. Length 2.8 mm., width 1.3 mm. Head: width .64 mm., vertex .29 mm.; brown, lower face more yellowish. Rostrum, length 1.06 mm., reaching upon hind coxæ, yellowish, apex blackish. Antennæ: segment I, length .25 mm., pale yellowish, a red mark at base; II, .95 mm., gradually thickened apically, where it equals thickness (.089 mm.) of segment I, pale, uniformly pale yellowish; III, .53 mm., equal to thickness of segment II, yellowish, apical half reddish; IV, .38 mm., equal to thickness of segment III, reddish. Pronotum: length .53 mm., width at base 1 mm.; impunctate, brown to dark brown, a tinge of red sometimes apparent. Scutellum impunctate, yellowish to dusky; sternum yellowish brown, reddish brown on pleura.

Clothed with fine, short, simple, pale pubescence. Hemelytra pale yellowish, inner apical angles of corium pale fuscous; cuneus red to brownish, apex and outer margin more yellowish. Legs uniformly pale yellowish, hind femora reddish except on base. Venter uniformly yellowish, reddish brown on sides at base.

Holotype: ♀, October 11, 1914, Laurel, Maryland (W. L. McAtee); collection of W. L. McAtee.

Paratypes: ♀, taken with type. ♀, July 12, 1914, Odenton, Maryland (J. D. Hood).

Ceratocapsus downesi new species.

Runs to *pumilus* Uhler in my key (Hem. Conn., 1923, p. 525), but differs in the more slender form and brownish black color, shorter antennal segment II, narrower vertex, and very different male genitalia.

♂. Length, 4.3 mm., width, 1.5 mm. Head: width, .80 mm., vertex .23 mm. Rostrum, (imbedded) probably reaching upon hind coxæ. Antennæ: segment I, length, .27 mm.; II, .97 mm.; III, .58 mm.; IV, .51 mm. Pronotum: length, .62 mm., width at base, 1.28 mm.

Dorsum rather closely and uniformly punctured as in *pumilus*; pubescence very similar to *pumilus*. General coloration brownish black,

hemelytra somewhat translucent so that the punctures appear darker, cuneus blackish with a trace of red in hypodermis; legs pale to brownish black. Membrane pale fuscous, apical half and veins somewhat darker. Genital segment and claspers much more reduced than in *pumilus*; right clasper reduced to a minute rounded knob, but supporting three or four long hairs; left clasper with only two small slender prongs.

Holotype: ♂, July 30, 1922, Saanich District, British Columbia (W. Downes); Canadian National collection.

Paratypes: ♂, Sept. 6; ♂, Sept. 11; ♂, Sept. 14, 1918, Saanich District, B. C. (W. Downes); ♂, Sept. 14, Victoria, B. C. (W. Downes).

Ceratocapsus biformis new species.

Allied to *drakei* Kngt., but distinguished by the dark color, relatively shorter antennal segments, red head and legs, and in structure of the male genital claspers.

♂. Length, 4.9 mm., width, 1.6 mm. Head: width, .74 mm., vertex .28 mm. Rostrum, length, 1.4 mm., reaching upon middle of the hind coxæ. Antennæ: segment I, length, .40 mm., yellowish red; II, 1.4 mm., yellowish brown, becoming brownish black on apical half; III, .84 mm., blackish; IV, .54 mm., black. Pronotum: length, .60 mm., width at base, 1.23 mm.

Punctuation and pubescence nearly as in *drakei*. Color brownish black to black, head, cuneus, and legs bright red, legs sometimes paler, especially on coxæ and bases of femora. Membrane dark fuscous, somewhat paler transversely across apical half of areoles. Genital claspers having the same general form of *drakei*, but right clasper with shorter and more strongly recurved dorsal prong, while the lower prong follows the wall of the genital segment for half its length then turns sharply upward, the bend of the elbow produced into a spear-shaped heel.

♀. Brachypterous, length, 2.7 mm., width, 1.5 mm. Head: width, .73 mm., vertex, .34 mm. Rostrum, length, 1.33 mm., extending upon hind coxæ. Antennæ: segment I, length, .33 mm.; II, 1.03 mm.; III, .64 mm.; IV, .47 mm. Pubescence, punctuation, and coloration very similar to the male, but pronotum more reddish. Hemelytra rounded at apex, cuneus short and rounded, with only a trace of membrane present, cuneal fracture apparent.

Holotype: ♂, August 15-22, 1924, Pingree Park, Colorado (Drake & Hottes); author's collection.

Allotype: Same data as the type.

Paratypes: 6 ♂ 3 ♀, taken with the types. ARIZONA—♀, July 27, 1917, Mt. Lemon, alt. 9000 ft., Santa Catalina Mts., (H. H. Knight); ♂ ♀, August 3, 1905, Huachuca Mts. (H. G. Barber). COLORADO—2 ♀, July 24, 1909, Golden (W. J. Gerhard); 3 ♂ 5 ♀, June 12, 1900, Fort Collins; 2 ♂ ♀, June 13, 1898, Rist

Canyon (E. D. Ball). MONTANA, ♂, September 3, 1912, Bozeman. ♂ 2 ♀ June 24, 1925, Williams, Arizona (A. A. Nichol).

This species was obtained by Drake and Hottes by sweeping grasses and sedges.

Ceratocapsus tricolor new species.

Allied to *biformis*, but distinguished by the genital claspers, black color with pale yellowish clavus and reddish femora.

♂. Length 5 mm., width 1.48 mm. Head: width .77 mm., vertex .31 mm.; eyes finely pubescent. Rostrum, length 1.4 mm., reaching to middle of hind coxæ, blackish. Antennæ: segment I, length .41 mm., yellowish, blackish on the constricted basal one-fourth; II, 1.6 mm., cylindrical, scarcely equal to thickness of segment I, black, slightly yellowish at base, finely yellowish pubescent; III, .98 mm., scarcely equal to thickness of segment II, black; IV, .68 mm., slightly more slender than III, black. Pronotum: length .59 mm., width at base 1.11 mm.; impunctate, scutellum likewise impunctate, but the hemelytra with fine setigerous punctures apparent. Ostiolar peritreme with dorsal lobe broadly convex, whereas *biformis* has a small convex area.

Clothed with long, erect, golden yellow simple pubescence; devoid of the silvery scale-like hairs found in *biformis*. Black, moderately shining, hemelytra more of a fuscous black, clavus pale yellowish translucent, embolium usually somewhat yellowish; membrane pale, apical half fuscous, femora reddish, becoming darker at base; coxæ pale, fuscous at base, front pair reddish to piceous; tibiae reddish brown to fuscous, tarsi yellowish, blackish apically. Genital claspers distinctive, right clasper with the ventral arm broadly arcuate, not sharply bent as in *biformis*, the dorsal arm flattened, bifid on apex.

Holotype: ♂, August 13, 1925, Mancos, Colorado (H. H. Knight); author's collection.

Paratypes: ♂, August 9, 1925, Veta Pass, alt. 8500 ft.; ♂, August 12, 1925, South Fork, Colorado (H. H. Knight). These specimens were swept from mixed growth of sedges in damp places, which seems to indicate the type of habitat.

Ceratocapsus fulvipennis new species.

Runs to *sericus* Kngt. in my key (Hem. Conn., 1923, p. 525), but differs in the smaller size, more abundant erect hairs, intermixed with fine, golden yellow, sericeous pubescence.

♂. Length 4 mm., width 1.48 mm. Head: width .74 mm., width of vertex at base .326 mm., narrowest point forward .281 mm.; eyes finely pubescent. Rostrum, length 1.18 mm., reaching to middle of hind coxæ. Antennæ: segment I, length .25 mm.; II, 1.06 mm., equal

in thickness (.09 mm.) to segment I, slightly more slender near base; III, .62 mm., equal in thickness to segment II; IV, .53 mm., slightly more slender than III; brownish yellow, last two segments fuscous. Pronotum: length .56 mm., width at base 1.2 mm.; impunctate although minutely rugulose, scarcely shining.

Clothed with rather abundant, long erect hairs, and intermixed with shorter simple pubescence, and fine prostrate, sericeous, golden yellow pubescence. Color yellow brown to dark brown, pronotum somewhat darker than head, scutellum more yellowish than brown; hemelytra fulvous, subtranslucent, embolium and cuneus of somewhat deeper color. Membrane uniformly fuscous, areoles somewhat paler. Legs reddish brown to dark brown, tibiae scarcely paler; venter and sternum of the same brown color, shining.

Holotype: ♂, August 7, 1925, Stonewall, alt. 8500 ft., near Trinidad, Colorado (H. H. Knight); author's collection.

Paratype: ♂, taken with the type on pine, probably *Pinus ponderosa*.

A CHECK LIST OF THE CARABIDÆ OF COLUMBUS, OHIO, AND VICINITY.

R. T. EVERLY

This list is based on work done at the Ohio State University under the direction of Dr. Herbert Osborn. The insects listed are from the University collection, from a list of the insects of the Ohio State Campus collected by A. E. Miller, and from my own collection. The list is not complete but gives a good representation of the species common to Central Ohio. It includes 59 genera and 133 species.

CARABINÆ

- | | |
|---|---|
| 1. <i>Carabus</i> —Linn.
<i>limbatus</i> —Say.
<i>vinctus</i> —Web. | 5. <i>Nebria</i> —Latr.
<i>pallipes</i> —Say. |
| 2. <i>Calosoma</i> —Web.
<i>externum</i> —Say.
<i>scrutator</i> —Fab.
<i>wilcoxi</i> —Lec.
<i>calidum</i> —Fab. | 6. <i>Scarites</i> —Fab.
<i>subterraneus</i> —Fab.
<i>substriatus</i> —Hald. |
| 3. <i>Elaphrus</i> —Fab.
<i>ruscarius</i> —Say. | 7. <i>Dyschirus</i> —Bon.
<i>globulosus</i> —Say.
<i>haemorrhoidalis</i> —Dej. |
| 4. <i>Notiophilus</i> —Dum.
<i>semistriatus</i> —Say.
(<i>sibiricus</i> —Cr.) | 8. <i>Clivina</i> —Latr.
<i>impressifrons</i> —Lec.
<i>punctigera</i> —Lec.
<i>pipustulata</i> —Fab. |
| | 9. <i>Ardistomus</i> —Putz.
<i>viridis</i> —Say. |

HARPALINÆ

- | | |
|--|--|
| 10. <i>Panagaeus</i> —Latr.
<i>fasciatus</i> —Say. | 14. <i>Gastrellarius</i> —Csy.
<i>honestus</i> —Say. |
| 11. <i>Bembidion</i> —Latr.
<i>inacquale</i> —Say.
<i>confusum</i> —Hayw.
<i>laevigatum</i> —Say.
<i>planum</i> —Hald.
<i>chalcum</i> —Dej.
<i>patrule</i> —Dej.
<i>intermedium</i> —Kby.
<i>dorsale</i> —Say.
<i>variegatum</i> —Say.
<i>affine</i> —Say.
<i>impotens</i> —Csy.
(<i>pictus</i> —Lec.)
<i>decipiens</i> —Dej.
<i>quadrimaculatum</i> —Linn. | 15. <i>Eumolops</i> —Csy.
<i>furtiva</i> —Lec.
<i>sodalis</i> —Lec. |
| 12. <i>Patrobus</i> —Dej.
<i>longicornis</i> —Say. | 16. <i>Evarthrus</i> —Lec.
<i>orbatus</i> —Newm. |
| 13. <i>Pterostichus</i> —Bon.
<i>*femoralis</i> —Kby.
<i>*hamiltoni</i> —Horn.
<i>*patruellis</i> —Dej.
<i>*sayi</i> —Brulle. | 17. <i>Euferonica</i> —Csy.
<i>stygica</i> —Say.
<i>coracina</i> —Newm. |
| | 18. <i>Abacids</i> —Lec.
<i>permundus</i> —Say. |
| | 19. <i>Pocillus</i> —Bon.
<i>chalcites</i> —Say.
<i>lucublandus</i> —Say. |
| | 20. <i>Dysidius</i> —Chaud.
<i>mutus</i> —Say. |
| | 21. <i>Stereocerus</i> —Kby.
<i>heamatopus</i> —Dej. |
| | 22. <i>Dradytus</i> —Steph.
<i>scharwzi</i> —Hayw. |
| | 23. <i>Amara</i> —Bon.
<i>fallax</i> —Lec.
<i>cupreolata</i> —Putz.
<i>*exarata</i> —Dej. |

*Not listed in Leng's check list, but is in Henshaw's.

24. *Triacna*—Lec.
 angustata—Say.
25. *Rembus*—Latr.
 (*Diplocheila*—Brulle.)
 laticollis—Lec.
26. *Dicaelus*—Bon.
 dilatus—Say.
 purpuratus—Bon.
 sculptilis—Say.
 elongatus—Bon.
 teter—Bon.
27. *Badister*—Clairv.
 notatus—Hald.
28. *Calathus*—Bon.
 gregarius—Dej.
29. *Platynus*—Bon.
 hypolithus—Say.
 sinuatus—Dej.
 brunneomarginatus—Mann.
 extensicollis—Say.
 var. *viridis*—Lec.
 decorus—Say.
 affinis—Kby.
 cupripennis—Say.
 excavatus—Dej.
 ferreus—Hald.
 nutans—Say.
 octopunctatus—Fab.
 placidus—Say.
 bembidioides—Kby.
 rubripes—Lec.
 punctiformis—Say.
30. *Atranus*—Lec.
 pubescens—Dej.
31. *Casnonia*—Latr.
 pennsylvanica—Linn.
32. *Leptotrachelus*—Latr.
 dorsalis—Fab.
33. *Galerita*—Fab.
 janus—Fab.
 bicolor—Drury.
34. *Lebia*—Latr.
 grandis—Hentz.
 atriventris—Say.
 viridis—Say.
 ornata—Say.
 analís—Dej.
 scalpularis—Dej.
35. *Calleida*—Dej.
 punctata—Lec.
36. *Pinacodera*—Schaum.
 limbata—Dej.
37. *Blechrus*—Motsch.
 glabratus—Duft.
 (*nigrinus*—Mann.)
38. *Helluomorpha*—Lap.
 bicolor—Harris.
39. *Cymindis*—Latr.
 pilosa—Say.
40. *Brachinus*—Web.
 americanus—Lec.
 viridipennis—Dej.
 var. *perplexus*—Dej.
 conformis—Dej.
41. *Chlaenius*—Bon.
 tomentosus—Say.
 impunctifrons—Say.
 pennsylvanicus—Say.
 brevilabris—Lec.
 tricolor—Dej.
 nemoralis—Say.
 leucocelis—Chev.
 aestivus—Say.
 diffinis—Chd.
 sericeus—Forst.
42. *Anomoglossus*—Chd.
 pussilus—Say.
43. *Geopinus*—Lec.
 incrassatus—Dej.
44. *Cratacanthus*—Dej.
 dubius—Beauv.
45. *Harpalus*—Latr.
 calaginosus—Fab.
 compar—Lec.
 pennsylvanicus—DeG.
 (*faunus*—Lec.)
 herbivagus—Say.
46. *Gynandrus*—Dej.
 hylacis—Say.
47. *Tripectus*—Lec.
 rusticus—Say.
48. *Anisodactylis*—Dej.
 harrisii—Lec.
 nigerrimus—Dej.
 melanopus—Hald.
 (*agricola*—Lec.)
49. *Amphasia*—Newm.
 interstitialis—Say.
50. *Pseudamphasia*—Csy.
 sericeus—Harris.
51. *Anadaptus*—Csy.
 discoides—Dej.
 baltimorensis—Say.
52. *Anisotarsus*—Chd.
 terminatus—Say.
53. *Triliarthrus*—Csy.
 artimediús—Say.
54. *Stenocellus*—Csy.
 ruprestris—Say.
55. *Goniolophus*—Csy.
 rectangulus—Chd.
56. *Acupalpus*—Latr.
 carus—Lec.
57. *Stenolophus*—Dej.
 ochropezus—Say.
 fulginosus—Dej.
 conjunctus—Say.
58. *Tachistodes*—Csy.
 partiaris—Say.
59. *Agonderus*—Dej.
 lineola—Fab.
 pallipes—Fab.

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No. 4

REPORT OF THIRTY-SEVENTH ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

The Thirty-seventh Annual Meeting of the Ohio Academy of Science was held at the Ohio State University, Columbus, on April 15 and 16, 1927, under the presidency of Dr. William McPherson. Approximately 150 members and quite a large number of visitors were in attendance at the various general and sectional meetings. As shown elsewhere in this report, the scientific program contained a large number of excellent papers and addresses, covering a wide range of topics, many of them eliciting an unusual interest.

Sixty-nine new members were elected so that at the close of the meeting the membership of the Academy stood at 503.

The following is the general program of the meeting:

FRIDAY, APRIL 15.

- 9:00 A. M.—Business meeting.
- 10:30 A. M.—Presentation of papers in general session.
- 1:00 P. M.—Presentation of papers in sectional meetings.
- 6:30 P. M.—Annual banquet, Ohio Union.
- 8:00 P. M.—Invitation address by Prof. C. E. McClung, Professor of Zoology, University of Pennsylvania, on "The Mechanism of Heredity," in the University Chapel.

SATURDAY, APRIL 16.

- 8:30 A. M.—Adjourned business meeting.
- 9:30 A. M.—Presentation of papers in general session, including a lecture by Dr. Robert A. Millikan, Director of the Norman Bridge Laboratory of Physics, California Institute of Technology, on "The Birth of a Light Ray."

MINUTES OF THE BUSINESS MEETINGS.

The first business meeting was called to order by President McPherson at 10 A. M., Friday, April 15, 1927, in Room 100 of the Botany and Zoology Building, Ohio State University, with about 50 members present.

The President announced the following committee appointments:

Committee on Membership—Geo. D. Hubbard, H. M. Benedict, W. H. Shideler.

Committee on Resolutions—E. L. Moseley, W. F. Mercer, H. M. Benedict.

Committee on Necrology—L. B. Walton.

The Academy then proceeded to the election of an *Auditing Committee*. S. R. Williams and F. C. Waite were elected.

The following *Nominating Committee* was elected by ballot by the Academy: S. R. Williams, R. J. Seymour, C. F. Moses, M. E. Stickney, W. H. Alexander, and Harold E. Burr.

The reports of the following officers and standing committees were called for, read and ordered filed: The Secretary, the Treasurer (read by Prof. Herbert Osborn in the absence of the Treasurer), the Executive Committee, the Publications Committee (no report), the Trustees of the Research Fund, the Library Committee, and the Committee on State Parks and Conservation.

A second business meeting was held in the same place on Saturday, April 16, at 8:45 A. M. President McPherson opened the meeting by extending words of welcome and good wishes on behalf of President Rightmire, President of the Ohio State University, who was unable to be present. At this meeting the reports of special committees on membership, nominations, necrology, auditing, and resolutions were made and accepted.

On motion of Dr. R. J. Seymour, seconded by Prof. F. O. Grover, it was voted to adopt the recommendation of the Executive Committee amending Chapter 1, Section 1, of the By-Laws, increasing the annual dues of the Academy from \$2.00 to \$2.50 per year, effective at the beginning of the next fiscal year.

It was also agreed that the sum of \$1.50 per member should be paid annually to the *Ohio Journal of Science*.

Upon motion duly seconded the Academy extended a vote of thanks to the *Ohio Journal of Science* for its splendid cooperation and contributions in the past.

Upon motion of Dr. Edward L. Rice, seconded by Prof. L. B. Walton, the question of immediate financial relief to the *Ohio Journal of Science* was referred with power to the incoming Executive Committee.

At the suggestion of the chairman of the Auditing Committee it was voted to refer the Treasurer's report to the auditor of the Ohio State University for final auditing. (The chairman explained that this action is necessary because of the insufficiency of the data in the possession of the Auditing Committee, due to the sudden and unexpected absence of the Treasurer from the meeting).

The amendment to the Constitution proposed at the last annual meeting (see Ann. Rep., 36th Meeting, p. 25), amending Article III, Membership, was briefly explained by the Secretary and unanimously agreed to.

At the suggestion of the chairman of the Committee on State Parks and Conservation, the President was authorized to appoint a sub-committee from the Standing Committee on State Parks and Conservation to work with the State Forester in the formulation of regulations for the protection of the plant and animal life of the State forests.

The Secretary then read a communication from Prof. H. M. Benedict extending an invitation from the University of Cincinnati to the Ohio Academy of Science to hold the next annual meeting in Cincinnati. Moved by Professor Walton that the Academy express its appreciation of the invitation and that the matter be referred without recommendation to the Executive Committee. Carried.

The Secretary was requested to extend the greetings and good wishes of the Academy to Mr. Joe H. Todd, Wooster, in recognition of his having "traveled past his 90th milestone."

Adjourned 9:40 A. M.

REPORTS.

Report of the Secretary.

COLUMBUS, OHIO, April 15, 1927.

To the Ohio Academy of Science:

The routine affairs of the secretary's office—and they were more numerous than ever and increasing—were taken care of as promptly and as efficiently as circumstances would permit.

The first task of major importance after the last annual meeting was the preparation of the minutes of the meeting and the reports of officers and committees for publication as the "Proceedings of the Ohio Academy of Science," Thirty-sixth Meeting. Through the courteous cooperation of the Publications Committee and the Editor of the *Ohio Journal of Science* these proceedings were ready for distribution very much earlier than usual, together with a suitable title page and contents to Volume VII. prepared by Mrs. Ethel M. Miller. A summary was also prepared for and published in *Science*.

In the latter part of May (May 28, 29 and 30, 1926) the Geology Section of the Academy, under the leadership of Vice-President Wilber Stout, ably assisted by Prof. J. Ernest Carman, organized and successfully carried out a field trip into northern Ohio for an inspection and study of the Silurian and Devonian Systems of the Sandusky Bay Region. This trip took the party into Seneca, Sandusky, Ottawa and Erie counties. We commend the Geology Section on its field work.

The Ohio Academy of Science having received a very courteous invitation from the President, the Trustees and the Faculty of Western Reserve University, in the City of Cleveland, to be represented at the ceremonies commemorating its Centennial on the 12th and 13th of November, 1926, the Secretary with the hearty approval of the President requested Dr. Dayton C. Miller, of the Case School of Applied Science, to act as the representative of the Academy on this occasion. Dr. Miller kindly agreed to do so and sends the following report:

CLEVELAND, OHIO, March 9, 1927.

*The Ohio Academy of Science, Dr. W. H. Alexander, 16 East Broad Street,
Columbus, Ohio.*

MY DEAR DR. ALEXANDER:—In accordance with your request, I attended the ceremonies commemorating the Centennial of Western Reserve University held on November 12 and 13, 1926. I presented the greetings of The Ohio Academy of Science and formally signed the book of delegates representing the Learned Societies of America. I attended various exercises. The principal subjects considered were the Junior College Movement, the Training of Teachers and Research and Training for Research. A number of important addresses were given. I am enclosing a program which gives the details regarding the various papers presented. I am, also, enclosing the formal list of delegates. You will find the Ohio Academy of Science listed near the top of the fourth page of the list.

I am sure that the University appreciated the interest and good will of the various societies which sent delegates and it was a privilege and an honor to be permitted to represent the Ohio Academy of Science.

Very truly yours,

DAYTON C. MILLER.

As shown on page 25 of the Proceedings of the Thirty-sixth Annual Meeting, the Treasurer, Dr. A. E. Waller, was made the representative of the Academy at the International Botanical Congress that assembled at Ithaca, N. Y., in August, 1926, and as such Doctor Waller submits the following report of the meetings:

COLUMBUS, OHIO, August 30, 1926.

Dear Mr. Alexander:

As delegate of the Ohio Academy of Science, I attended the International Plant Congress held at Ithaca, New York, during the period of August 16th to 23rd. Over eight hundred members attended and all countries engaged in productive scientific work were represented. Most of the addresses were read by the foreign delegates, but round table discussions and informal conversations formed an important phase of the Congress.

I was so fortunate as to be asked by Professor Schaffner to accompany him in the journey east, thereby cutting in half my railroad expenses.

With all good wishes,

Sincerely yours,

A. E. WALLER.

The Secretary attended the Philadelphia meeting of the American Association for the Advancement of Science, in December, 1926, and represented the Academy at all meetings of the Council. He was honored by the President of the Association with appointment on the nominating committee of five and also served as one of the two tellers at the election of the President. On December 29, 1926, at an informal meeting of the representatives of the affiliated state academies at which eleven of the nineteen affiliated academies were represented it was decided to form a temporary organization and the undersigned was made the temporary chairman. The purpose of this meeting, as stated by Dr. McGill, secretary of the Tennessee Academy of Science, at whose suggestion the meeting was called, was:

"To effect an organization of the representatives of the affiliated state academies in the Council of the American Association for the Advancement of Science at this time in order to arrange for a possible round-table discussion by the representatives on the occasion of the next meeting of the American Association for the Advancement of Science at Nashville, Tennessee, in December, 1927."

In the latter part of March of this year, we received a letter from the Permanent Secretary of the American Association for the Advancement of Science, Dr. Burton E. Livingston, advising that the Association was planning a special campaign for new members and that a portion of the campaign would be related to the affiliated academies of science, and inclosing the first draft of the proposed circular letter regarding which he asked for critical suggestions. The letter as approved, gives due emphasis to the arrangement of affiliation between the academies and the Association. Doubtless by this time all members of the Ohio Academy who are not already members of the A. A. S. have received this letter and we hope have given it very careful consideration. As you know, members of the Academy under the terms of affiliation, are exempt from the payment of the \$5.00 initiation fee and fifty cents out of the \$5.00 annual dues is returned to the Academy.

In this connection, it may be proper to say that during the past few weeks the secretary has given much time and effort in calling to the attention of persons eligible to membership the claims of the Academy and through the cordial cooperation of members of the Academy we are able to present for your consideration at this meeting 43 nominees for membership.

Respectfully submitted,

WILLIAM H. ALEXANDER, *Secretary*.

Treasurer's Report for the Year 1926-1927.

To the Ohio Academy of Science:

Your Treasurer submits the following report of the financial condition of the Academy. The period covered is from April 1, 1926, to March 31, 1927.

RECEIPTS.

Cash Balance of April 1, 1926.....	\$ 716.08
Interest on certificate of deposit.....	39.00
Dues from members and allowance from the A. A. A. S.....	922.14
Total receipts, Exhibit A.....	\$1,677.22

DISBURSEMENTS.

C. E. Wilson, for Academy poster.....	\$ 1.50
The Neil House, Dr. Johnson's account.....	17.30
Wm. H. Alexander, Secretarial expenses.....	22.67
Wm. H. Alexander, Secretary's honorarium.....	100.00
Dr. Douglas Johnson, travel expenses for lecture.....	54.00
Diehl Office Equipment Company.....	1.85
A. E. Kraus Print Shop, programs, etc.....	86.00
Hiss Stamp Company.....	1.15
Wm. H. Alexander, Secretarial expenses.....	4.88
Spahr & Glenn Company, bill forms and envelopes.....	5.00
The Columbian Building & Loan Company, certificate of deposit.....	350.00
A. E. Waller, travel expenses to International Plant Congress.....	19.72
Helen Coleman, assistance to Treasurer.....	9.24
Spahr & Glenn Company, 600 due slips.....	3.75
Postmaster, Columbus, Ohio, stamped envelopes.....	26.92
C. G. Shatzer, expenses for attending executive meeting.....	2.50
Spahr & Glenn Company, envelopes.....	3.25
Mrs. Katherine D. Sharp, refund on overpayment.....	2.00
Schmitt Printing Company.....	24.25
W. H. Alexander.....	33.90
The Ohio Journal of Science for 1927 account.....	400.00
Eight returned checks for \$2.00 each.....	16.00
Total disbursements, Exhibit B.....	\$1,185.88

BALANCE SHEET.

Exhibit A—Receipts.....	\$1,677.22
Exhibit B—Disbursements.....	1,185.88

Cash balance on hand April 1, 1927..... \$ 491.34

There is one uncanceled check outstanding. The Secretary's honorarium has always been paid at the beginning of the period following the Annual Election and is to be deducted from the present balance.

The same is true for the expenses of the present meeting. Against this, there will be some additional income from the allowance of the A. A. A. S. and the sale of publications. But there is no denying the fact that there will be a smaller balance in the Treasury than last year. The disbursements are about one hundred and fifty dollars greater during the past calendar year than during the 1925-1926 period. Estimating the current liabilities from last year's there will probably be an unexpended balance of one hundred and fifty dollars in the Treasury to last until the next collection of membership dues.

Respectfully submitted,

A. E. WALLER, *Treasurer.*

Report of the Auditing Committee.

COLUMBUS, OHIO, April 16, 1927.

To the Ohio Academy of Science:

Technically there is nothing here to audit—no bank books, vouchers, receipts, etc. The mathematics presented is correct. The committee recommends that the report when completed be sent to the auditor of the Ohio State University with request that he audit same.

Respectfully submitted,

S. R. WILLIAMS,

F. C. WAITE,

Auditing Committee.

Report of the Executive Committee.

COLUMBUS, OHIO, April 15, 1927.

To the Ohio Academy of Science:

The Executive Committee held three meetings during the year now ending.

The first meeting was held, at the call of the President, on October 23, 1926, at the Faculty Club rooms, Ohio State University, with the President and three members (Shatzer, Waller and Alexander) present. The following items of business were presented, discussed and agreed upon:

1. The action of the President and Secretary in designating Dr. Dayton C. Miller as the representative at the ceremonies commemorating the Centennial of the Western Reserve University at Cleveland was approved.
2. Four nominations to membership in the Academy were approved.
3. The resignation of Prof. Charles H. Skinner from the office of Vice-President of the Physical Sciences Section was accepted.
4. The matter of additional financial support to the Ohio Journal of Science, referred to this committee by the Executive Committee last year (see page 25, Pro. 36th Ann. Meeting), was discussed and it was finally decided to arrange another meeting of the Executive Committee at an early date and to invite the editor and business manager of the

Journal to be present and give the committee a full statement of the needs, proposed plans, etc., of the Journal.

5. That Mrs. Ethel M. Miller be made a member of the Academy without dues and that the action of the President in putting her in charge of all Academy publications be approved.

6. That the actual travelling expenses of the Executive Committee when in attendance at its meetings be paid out of the funds of the Academy.

7. That an intensive campaign for new members be inaugurated at once under the leadership of the Treasurer, Dr. A. E. Waller.

The second meeting of the Committee was held at the hospitable home of President and Mrs. McPherson, 198 Sixteenth Avenue, Columbus, on December 16, 1926, with all members of the committee present and, by invitation, Dr. F. H. Kreckler, editor of the *Ohio Journal of Science*; Prof. L. H. Tiffany, business manager of the *Ohio Journal of Science*, and Dr. J. H. Schaffner, a member of the editorial board of the *Journal*. The following matters of business were taken up and disposed of:

1. Five applications for membership in the Academy were presented and approved.

2. Prof. Alpheus W. Smith was unanimously elected Vice-President of the Physical Sciences Section, vice Prof. Charles H. Skinner, resigned.

3. The primary purpose of the meeting was then taken up, namely, the matter of additional financial support from the Academy to the *Ohio Journal of Science*. The editor and the business manager of the *Journal* then presented a detailed financial statement for the years 1921, 1922, 1923, 1924, 1925 and 1926, and concluding with the following general statements:

SUMMARY STATEMENTS.

1. During the world war and because of inadequate funds previously, the Journal had accumulated a deficit of nearly \$800.00 when the present manager was appointed.

2. That deficit will be decreased to about \$600.00 by the end of 1926.

3. Since the printers do not render accounts till the end of the year, and since the University allowance and the Academy dues are paid in advance, we are able to meet one year's bills by the next year's allowances.

4. The balance remaining is uncomfortably small, even if we had the deficit removed.

5. This situation gives no opportunity for expansion on the part of the Journal.

6. Authors must pay for all cuts for articles and this is not required by any other scientific publication.

Doctor Kreckler pointed out that the *Journal* was seriously handicapped not only by the deficit that has been running for several years, but by lack of funds with which to expand, and expressed the feeling that in view of the service rendered by the *Journal* to the Academy, the Academy could well increase its support, at least to the extent of 50

cents per member. Professor Schaffner was also of the same opinion and expressed the further belief that many members joined the Academy solely for the *Journal*.

After considerable discussion, pro and con, it was finally voted that the Executive Committee recommend to the Academy at its next annual meeting that the By-Laws (Chapter 1, Section 1) be so amended as to increase the annual dues from \$2.00 per annum to \$2.50 per annum and that of this amount \$1.50 be paid to the *Ohio Journal of Science*.

The third meeting of the committee was held at the Faculty Club rooms, Ohio State University, on January 31, 1927. At this meeting it was voted to accept the invitation of the Ohio State University to hold the next annual meeting of the Academy on its campus and the time for this meeting was fixed as April 15th and 16th, 1927.

It was also unanimously agreed that the Academy could do no better in the way of an invitation speaker than to accept the very generous offer of President McPherson to do what he could to so arrange the series of lectures by Dr. Robert A. Millikan, of California, that the members of the Academy could easily take advantage of them and thus hear from one to three. It was further agreed that effort should be made to secure Dr. J. H. McGregor, of Columbia University, and possibly Dr. C. E. McClung, of the University of Pennsylvania.

Respectfully submitted,

THE EXECUTIVE COMMITTEE,
By W. H. ALEXANDER, *Secretary*.

Report of the Trustees of the Research Fund.

To the Members of the Academy:

Our report this year may be very brief, as we have made no grants and, until yesterday, had received no applications. The funds have been invested and interest accumulations added so that we have a total fund to date of \$1,520.41, of which \$1,300.00 is invested in bonds and \$100.00 in certificate of deposit at interest.

Omitting the invested \$1,300.00, the account stands as follows:

Balance from last year.....	\$ 83.91
Interest additions.....	136.50
	<hr/>
Total.....	\$220.41
Invested in Certificate of Deposit.....	100.00
	<hr/>
Balance subject to check.....	\$120.41

Unless grants are made during the year, it will be our policy to invest so as to secure returns on the available funds, but we will be pleased to receive applications or recommendations for appropriate projects.

Respectfully submitted,

HERBERT OSBORN,
EDWARD L. RICE,
GEO. D. HUBBARD,
Trustees.

April 15, 1927.

Report of the Auditing Committee.

To the Ohio Academy of Science:

We find adequate vouchers showing for April 14, 1927, \$1,400.00 of invested funds and \$120.41 balance in checking account of Trustees of the Research Fund. This is in accord with the report made.

Respectfully submitted,

S. R. WILLIAMS,
F. C. WAITE,
Auditing Committee.

Report of the Committee on State Parks and Conservation.

(Informal)

Prof. Herbert Osborn, Chairman of the Committee on State Parks and Conservation, made an informal report stating that there had been no meeting of the committee and no formal report could be presented at this time. He stated that in connection with the question of preservation of the forest tracts, which offer perhaps the most promising field for the wider preservation of our native fauna and flora, that he had had a conference with Mr. Secrest, the state forester, and had been assured of his desire to aid in this matter and that he would welcome a special committee of advisers from the Academy to formulate regulations intended to preserve the biological status in the state forests. It is evident that the interests of tourists, picnickers, sportsmen, hunters, foresters and biologists are likely to clash at times and it is desirable to adopt plans for the different forest tracts that will meet the different purposes as fully as possible while providing the utmost security for the native plants and animals they contain.

To provide such a committee of advisers it was moved and voted that the President of the Academy be authorized to appoint a sub-committee of the standing committee on State Parks and Conservation to work with the State Forester in the formulation of regulations for the protection of the plant and animal life of the state forests.

(In compliance with the favorable action of the Academy on the above recommendation, President Benedict, on June 2, 1927, appointed the following sub-committee: Herbert Osborn, E. Lucy Braun and Arthur R. Harper).

Report of the Library Committee.

COLUMBUS, OHIO, April 15, 1927.

To the Ohio Academy of Science:

An accurate account of the accessions to the Academy Library of the past ten years has been secured during the year, and a card catalogue has been nearly completed giving in detail these records. The carrying through of this important work is due to enthusiasm and energy of Mrs. Ethel M. Miller, of the Botany-Zoology Library of the University, with the cooperation of the staff of the General University Library.

In 1917 the Academy voted that a suitable printed plate, to be paid for by the Academy, be put in the books given to the Ohio State University Library, and in its accessions.

The University Library possesses a handsome engraved Gift Book Plate which it would be glad to use in place of the Academy's very simple printed plate. The library will supply the plates and pay for the printing of "The Ohio Academy of Science" on them. The Library Committee of the Academy appreciates and accepts this offer for the Academy.

The sales of Academy publications by Mrs. Miller have been highly satisfactory. A statement of these sales is included in Mrs. Miller's appended report. The Chairman of the Committee has checked these sales and audited Mrs. Miller's books, and finds her accounts to be correct and her books to balance.

Respectfully submitted,

F. O. GROVER, *Chairman.*

Report of Mrs. Miller for the Ohio State University Library.

COLUMBUS, OHIO, April 15, 1927.

To the Ohio Academy of Science:

The year that has now passed has been an exceedingly busy and pleasant one. As the exchange work was wholly new to me, it took some time to familiarize myself with the periodicals and with the correspondence of the last ten years.

The card catalog is practically finished for the exchanges of the Academy, but is not yet complete for those that receive only the *Journal of Science*. Appreciation is due to the University Library assistance and the time necessary to do the work.

The sale of publications has gone on as usual, amounting to \$69.40 to date. Two sales, totaling \$8.50 have been made so recently that payment has not yet been received. The difference between these two sums, namely, \$60.90, is ready to be handed to the Treasurer, together with an additional sum of \$13.15, a check for which dated December 20, 1923, was found last summer in a filing case in the Botany office. The Treasurer asked me to deposit this check in my account and to hand it to him with the full amount of this year's sales. The interest on the sums deposited from the sales of the Academy Proceedings and Special Papers and the *Ohio Journal of Science* for the last half of 1926 amounted to \$1.84. The Treasurer agreed to let this remain on deposit.

The Proceedings of the Thirty-sixth Meeting were received in August and were mailed at once upon receipt of the title pages to 442 members and to 84 exchanges. The Academy publications and the *Ohio Journal of Science* have been sent to twenty-five institutions to fill in their sets of these publications and volumes have been received from thirty-five places to fill in our sets of their publications.

No systematic effort has been made to obtain new exchanges, but 41 have been secured with 34 institutions. Ten of these institutions will receive the Academy Proceedings and Special Papers, five will

receive both the Proceedings and the *Ohio Journal of Science* and to nineteen the *Journal* only will be sent. Eighteen former exchanges have been resumed.

I am hoping that as soon as it is possible to do so, the Academy will publish something in addition to the Proceedings to be used as an exchange and to be sold. It has now been fifteen years since the last Special Paper was published. As long as the Proceedings contain only the business reports of the meetings, practically the only new exchanges that can be secured are similar reports of other organizations. Sets of the Special Papers have been sent in several instances, but it seems only fair to continue to send something in return for a periodical that is being published and sent regularly to the Academy.

The most interesting feature of the work this year has been the correspondence with other institutions, both in this country and in all parts of the world.

Respectfully submitted,

ETHEL M. MILLER,

For Ohio State University Library.

Report of the Committee on the Election of Fellows.

To the Ohio Academy of Science:

A meeting of the Committee on the Election of Fellows was held in the office of the Graduate School, Ohio State University, Columbus, on the evening of April 14, 1927, with a quorum present. Of the candidates nominated and considered, seven received the necessary favorable votes and were declared elected. In accordance with custom, the Fellows will be personally notified, and the list will be published in the Proceedings of this meeting.

Respectfully submitted,

WILLIAM H. ALEXANDER,

Secretary, for the Committee.

Columbus, Ohio, April 16, 1927.

The following is a list of those elected Fellows:

J. HOBART HOSKINS
ARTHUR W. LINDSEY
GARRY CLEVELAND MYERS
A. SOPHIE ROGERS
EDMUND MAUTE SPIEKER
GRACE ANNE STEWART
ALLYN COATS SWINNERTON

Report of the Committee on Membership.

To the Ohio Academy of Science:

Applications, each signed by two members of the Academy, have been received from the following named persons and your committee unanimously recommends their election to membership in the Academy,

said membership to become effective upon the payment of one year's dues, viz.:

BABBITT, MISS RUTH VARIE, 325 W. Eighth Ave., Columbus.
BENNETT, MISS MARY, 101 N. Center St., Westerville.
BIELSTEIN, CLYDE H., Westerville.
BILLESON, T. J., Sinking Spring.
BRACKEN, MISS DOROTHY M., 1016 Eighth St., Lorain.
BRANT, ARTHUR M., Lord Hall, O. S. U., Columbus.
CHAMPION, MILTON M., Box No. 60, Men's Building, Oberlin.
CHASE, MISS CATHERINE, Baldwin Cottage, Oberlin.
CONDRI, J. M., 1890 East 105th St., Cleveland.
COOLEY, LUSTER MANNING, Ohio Agricultural Experiment Station, Wooster.
COPELAND, HERMAN A., 64 N. Congress St. (temp.), Athens.
COYLE, MISS ELIZABETH E., 360 E. Bowman St., Wooster.
CRUM, CARLOS L., Sinking Spring, Ohio.
CUYLER, W. KENNETH, Cleveland Museum Natural History, 2717 Euclid Ave., Cleveland.
DUNHAM, W. E., Ohio State University, Columbus.
EASTERLING, G. R., R. F. D. No. 4, Athens.
EDWARDS, RAY LEE, Physics Department, Miami University, Oxford.
ENGLE, O. H., 122 Rice St., Alliance.
FEARING, FRANKLIN, Ohio Wesleyan University, Delaware.
FIELDS, PAUL E., Delaware.
FITZGERALD, PAUL E., Harrod, Auglaize County.
FLETCHER, FRED, Miami University, Oxford.
FULFORD, MISS MARGARET, Sutton Ave., Mt. Washington, Cincinnati.
GANS, DR. HOWARD M., 1067 Thornhill Drive, Cleveland.
HALE, DR. KELLY, Wilmington.
HANSEN, WALTER, 190 E. College St., Oberlin.
HARROD, J. R., 213 E. University Ave., Ada.
HAYNES, JOHN, 33 W. Eleventh Ave., Columbus.
HEDRICK, JOYCE, 13 Bishop Hall, Oxford.
HERTZ, MRS. MARGUERITE R., 9511 Lamont Ave., Cleveland.
HOLSOPPLE, DR. QUINTER, Western Reserve University, Cleveland.
KAYSER, WILLIAM, 211 W. Mechanic St., Wapakoneta.
KEPLINGER, MRS. DOROTHEA DOANE, 3147 W. 88th St., Cleveland.
KILPATRICK, BETH, R. F. D. No. 3, Athens.
KIRK, JOSEPH M., 16 E. Broad St., Columbus.
LEIKIND, MORRIS C., 417 S. Monroe St., Columbus.
LIMING, O. NEAL, 231 S. Charity St., Bethel.
LIPPY, MISS GRACE E., 835 Woodlawn Ave., Springfield.
MCCAGHEY, WM. J., Dept. of Mineralogy, O. S. U., Columbus.
MCCLURE, O. E., 182 N. Congress St., Athens.
MCGILLIARD, MISS ELEANOR, 10 Parkway, Hartwell, (Cincinnati).
MCMURRAY, W. J., 201 Court St., Wapakoneta.
MCNELLY, WALTER C., 230 E. Church St., Oxford.
MEYERS, MARION T., Dept. of Farm Crops, O. S. U., Columbus.
MILLER, JOSEPH N., Department of Zoology, O. S. U., Columbus.
MOORE, GEORGE M., King Hall, Westerville.
MUNSON, ARTHUR L., 2914 E. 132d St., Cleveland.
NEISWANDER, RALPH B., 26 W. Frambes Ave., Columbus.
O'ROURKE, EDWARD V., Department of Mine Engineering, O. S. U., Columbus.
ODIORNE, JOSEPH M., Biological Laboratory, Western Reserve Univ., Cleveland.
OHMANN, DR. O. A., Dept. of Psychology, Western Reserve Univ., Cleveland.
PARK J. B., Ohio State University, Farm Crops, Columbus.
PEELE, MILES T., Wilmington, Ohio, (Temp. 1548 Michigan Ave., Columbus).
PITTINGER, WILLIAM J., 1008 Moeller Ave., Akron.
PORTER, JAMES P., Ohio University, Athens.
RICKLY, IRVIN B., 2063½ N. High St., Columbus.
RILLING, MISS PAULINE B., 920 S. Fourteenth St., New Castle, Ind.
SCHAEFER, J. E., 383 Oakland Park Ave., Columbus.
SCHAEFFER, JOHN W., 16 E. Broad St., Columbus.

SCHNEIDER, MISS ELIZABETH, 514 N. Wittenberg Ave., Springfield.
 SIMMONS, GEORGE FINLAY, Cleveland Museum Natural History, Cleveland.
 SLEESMAN, J. P., 128 W. Lane Ave., Columbus.
 SMITH, G. L., 618 S. Main St., Ada.
 SNIDER, GEORGE GOULD, Dept. of Zoology, University of Cincinnati, Cincinnati.
 VAUGHN, LLOYD D., R. F. D. No. 1, Carrothers.
 WALKER, CHARLES F., 53 Latta Ave., Columbus.
 WEBSTER, CHARLOTTE E., 300 Washington Ave., Elyria.
 WILLIAMSON, ERNEST W., Belfast, Ohio.
 YOUNG, BOYD B., 1104 Garfield Ave., Springfield.

Respectfully submitted,

GEORGE D. HUBBARD, Chairman,
 W. H. SHIDELER,

Committee.

Unanimously approved.

Report of the Nominating Committee.

President—HARRY M. BENEDICT.

Vice-Presidents:

Zoology—ARTHUR W. LINDSEY.

Botany—HOMER C. SAMPSON.

Geology—ALLYN C. SWINNERTON.

Medical Sciences—EMERY R. HAYHURST.

Psychology—A. SOPHIE ROGERS.

Physical Sciences—ALPHEUS W. SMITH.

Secretary—WILLIAM H. ALEXANDER.

Treasurer—A. E. WALLER.

Elective Members of Executive Committee—L. G. WESTGATE, L. B. WALTON.

Trustee Research Fund—EDWARD L. RICE.

Publications Committee—E. L. MOSELEY, AUG. F. FOERSTE, H. C. BEARDSLEE.

Library Committee—F. C. BLAKE.

Committee on State Parks—E. LUCY BRAUN, EDMUND SECREST, C. G. SHATZER.

Respectfully submitted,

S. R. WILLIAMS, *Chairman*,
 R. J. SEYMOUR,
 C. F. MOSES,
 M. E. STICKNEY,
 W. H. ALEXANDER.

Columbus, Ohio, April 16, 1927.

Report unanimously approved.

Report of the Committee on Necrology.

To the Ohio Academy of Science:

So far as known to your committee, the Academy has suffered the loss through death of but one member during the year just ended, namely, Prof. Edwin A. Hartley, of the New York State College of

Forestry. The following notes concerning the life and work of Professor Hartley were supplied by Dr. Herbert Osborn, of the Ohio State University:

EDWIN A. HARTLEY.

Our Academy has lost one of its very promising members in the death of Professor Edwin A. Hartley, of the New York State Forestry School, Syracuse University, Syracuse, New York. Professor Hartley died from an acute attack of appendicitis, October 15, 1926, at the age of thirty-three. He was formerly a resident of Oregon and studied at the Oregon Agricultural College, receiving his Bachelor of Science degree there in 1918. During his college career and for some time later he was employed in forestry work by the State of Oregon and the United States Forestry service. He entered Ohio State University in the fall of 1919, taking the graduate work in Entomology and serving as a graduate assistant, remaining in this position for two years, during which time he made an important study of parasitic Hymenoptera, and obtaining his Master of Science degree in 1921. He was engaged as an Entomologist for some time later in the Pennsylvania Bureau of Plant Industry, but in 1922 was elected to the position of Assistant Professor of Entomology in the Syracuse Forestry School, where he continued until the time of his death.

Professor Hartley was a man of very fine personality, a man who made a host of friends and who was very highly esteemed by all of his associates. He was an industrious, energetic student, quick to comprehend, resourceful in ideas, and the kind of student who is a satisfaction and pleasure to his instructors. It was during his connection in the Ohio State University that he became a member of the Ohio Academy of Science and this membership he has retained in his various positions since leaving the state. Aside from his membership in the Ohio Academy of Science, he was a member of a number of scientific associations, among them, the Sigma Xi, The American Association of Economic Entomologists, and the Entomological Society of America.

Respectfully submitted,

L. B. WALTON,
Committee.

Report of the Committee on Resolutions.

Resolved, That the Ohio Academy of Science expresses its thanks—

1. To the Columbus Chamber of Commerce for its cooperation in making this meeting a success by providing two clerks to take care of the registration of members, the sale of banquet tickets, the giving out of information, etc.
2. To the local committee for making such ample and adequate arrangements for this meeting.
3. To the Ohio State University for the use of its buildings and equipments.
4. To the Graduate School of the Ohio State University for making it possible for the members of the Academy to hear Dr. C. E. McClung and Dr. R. A. Millikan.

Respectfully submitted,

E. L. MOSELEY,
W. F. MERCER,
H. M. BENEDICT,
Committee.

Columbus, Ohio, April 16, 1927.

SCIENTIFIC SESSIONS.

The following is the complete scientific program of the meeting:

PUBLIC LECTURES.

The Mechanism of Heredity.....	DR. C. E. McCLEUNG
The Birth of a Light Ray.....	DR. R. A. MILLIKAN
Cosmic Rays.....	DR. R. A. MILLIKAN

PAPERS.

1. The physiological gradient and its relation to morphology.... W. H. CAMP
2. Science for non-scientists..... DAVID DIETZ
3. The primary plant associations of Ohio: Their distribution and their significance as habitat indices..... HOMER C. SAMPSON
4. Recent studies of the American eagle..... FRANCIS H. HERRICK
5. Sex and sex-determination in the light of observations and experiments on dioecious plants..... JOHN H. SCHAFFNER
6. The present status of Entomology as an applied biological science,
D. M. DELONG
7. The place of human biology in the college curriculum..... A. B. PLOWMAN
8. The apparent need for an elementary cytology course for undergraduate students of zoology and biology..... WALTER C. KRAATZ
9. Some of the more recent conceptions concerning the supporting tissue of the nervous system..... ERNEST SCOTT AND ROBERT A. MOORE
10. A greatly increased range of usefulness for the Leeds and Northrup multiple fixed value standard of self inductance..... R. L. EDWARDS
11. The Dr. B. R. Bales Collection of birds eggs..... JAMES S. HINE
12. The tracheal stalk as supports of the female copulatory organs of the Polydesmid millepedes..... S. R. WILLIAMS
13. The male Trichopetalum lunatum—Harger; one of the Milliped family, Chordeumidae..... R. A. HEFNER
14. Linkage studies in *Drosophila hydei*..... WARREN P. SPENCER
15. A survey of State fish hatcheries to determine the damage due to parasites..... RALPH V. BANGHAM
16. The automobile as a factor in the destruction of wild life.... LYNDY JONES
17. Relation of light to the attachment of sessile marine organisms with special reference to those causing fouling of ships' bottoms,
J. PAUL VISSCHER
18. A revisit to Carrol Island, Washington, after twenty years.... LYNDY JONES
19. The sensory hairs of *Tyroglyphus americanus*—Banks..... BIERLY LANDIS
20. Quantitative tests of the "poison gas" of certain Millipedes... FRED FLETCHER
21. The red bat as a mother..... E. L. MOSELEY
22. Catalase activity and sex..... W. H. CAMP
23. The Sporophylls of *Onoclea sensibilis*..... MAXIMILIAN BRAAM
24. Structure of some Pennsylvanian plants from Illinois..... J. HOBART HOSKINS
25. The inheritance of Brown Pericarp in maize..... MARION T. MEYERS
26. Relic colonies and their significance in the plant migrations of Ohio,
E. LUCY BRAUN
27. Seasonal variations in the physical properties of evergreen leaves,
BERNARD S. MEYER
28. Further studies on Hibernacula in aquatic plants..... H. H. M. BOWMAN
29. Life history and experimental study of soybeans..... H. L. BORST
30. A rational formula for the photosynthetic reaction..... R. B. GORDON
31. Control of sex-reversion in the tassel of Indian corn..... J. H. SCHAFFNER
32. Some hypertrophic developments of aerial organs when used as cuttings,
O. T. WILSON
33. Rapidity of sap rise in ten species of trees as calculated on the basis of Bose's theory..... H. M. BENEDICT
34. The Graphidaceæ of North America..... BRUCE FINK

35. Note on the relation of stem size to leaf number in *Ailanthus*. H. M. BENEDICT
36. Preliminary studies of Ascophyta and related forms on herbaceous legumes.....RODERICK SPRAGUE
(Introduced by H. M. BENEDICT)
37. The winter blooming of dandelions.....BRUCE FINK
38. The Arthoniaceæ.....MISS JOYCE HEDRICK
(Introduced by BRUCE FINK)
39. The genus *Hypoxylon* in Ohio.....DON CREAGER
(Introduced by BRUCE FINK)
40. The withering of flower-stalks.....MISS ELEANOR MCGILLIARD
(Introduced by H. M. BENEDICT)
41. Waste in clay mining in Ohio.....H. E. NOLD
42. The use of X-rays in mineral investigation.....WILLIAM J. MCCAUGHEY
43. South America as a future producer of crude petroleum.....E. V. O'ROURKE
44. The oil yield of samples of Ohio shale from Adams County,
WALTER H. BUCHER
45. Sponge spicules from the Sunbury shale.....WALTER H. BUCHER
46. Geology as a factor in soil classification in the New England States,
G. W. CONREY
47. Geology of Fort Ancient and Oregonia region, Warren County, Ohio,
J. J. WOLFORD
48. Grading of crude petroleum.....E. F. CLAGETT
49. Geologic section from the Adirondacks to the Green Mountains across
the Champlain Valley near Ticonderoga.....A. C. SWINNERTON
50. Relation of glauconite to unconformities.....J. E. SCHAEFER
51. Geological library facilities in Ohio.....GEN. EDWARD ORTON, JR.
52. Unveiling of portraits.
(a) W. W. Mather—Remarks by.....J. A. BOWNOCKER
(b) Edward Orton—Remarks by.....A. F. FOERSTE
53. Nature of geologic seas.....GEO. D. HUBBARD
54. Recent discoveries of Ordovician fossils of Richmond age in north-
western Greenland, and their bearing on the problem of climate in
early Paleozoic times.....A. F. FOERSTE
55. The economic importance of joints.....CHAS. H. BEHRE, JR.
56. Recent studies on early American Cephalopods, and their bearing on
the problem of the origin and evolution of Cephalopods.....A. F. FOERSTE
57. Olentangy shale in southern Ohio.....R. E. LAMBORN
58. Fossil footprints from the Pennsylvania System in Ohio.....J. E. CARMAN
59. Further data on old drainage in northeastern Ohio with some implications,
G. F. LAMB
60. A short description of the Millersburg oil and gas pool.....R. W. MELHORN
61. A comparison of the age with the number of somites in the white rat,
F. L. LANDACRE AND H. M. AMSTUTZ
62. The Spermatocytes of the first order in *Branchipus vernalis*,
R. C. BAKER AND C. A. ROSOF
(Introduced by F. L. LANDACRE)
63. The effect of the amount of protein in the previous diet and the nitrogen
excretion of the Albino rat during a fast,
F. A. HITCHCOCK AND A. L. RAWLINS
64. Silicosis; An X-ray study of 919 Ohio quarrymen (Stereo-Roentgenological
demonstration).....DANIEL J. KINDEL AND EMERY R. HAYHURST
65. Why the death rate for Columbus is higher than that for Toledo:
A statistical study.....RUTH E. MOORE AND EMERY R. HAYHURST
66. Deaths from heart disease in Ohio, with recommendations for the City
of Columbus: A statistical study.....EMERY R. HAYHURST
67. Lethal character of various vapors in confined spaces (rat demonstration),
FRED BERRY AND EMERY R. HAYHURST
68. Blood pressure in the rat.....ROLLIN R. DURANT
69. The prisms and interprismatic substance of the dental enamel,
SAMUEL W. CHASE
70. Some physico-chemical conditions necessary for light production by
luminous bacteria. (See demonstration No. 8).....O. L. INMAN

71. The breathing of combustion products in relation to pneumonia: An experimental study with white rats. EMERY R. HAYHURST
72. Form perception in the white rat. PAUL FIELDS
73. Muscular conditions in the after-image in reading. CARL N. REXROAD
74. Diagnosis and remedial instruction in reading. LUELLA C. PRESSEY
75. Psychological attributes of hysteria in children. FLORENCE MATEER
76. Advantages of various gross score formulae and checking formulae in statistical computation. HERBERT A. TOOPS
77. Analysis and treatment of rage in a two-year-old child,
MRS. MARGUERITE R. HERTZ
78. Classroom fears of junior high school pupils. MRS. HARRIET C. KEPLINGER
79. A study of the vocational interests of college women. O. A. OHMANN
80. A preliminary report on the technique of semi-circular canal extirpation in pigeons together with a tentative statement of results in connection with the recovery of equilibratory functions. FRANKLIN FEARING
81. A study on the causes and treatment of rage. MRS. DAVID RALPH HERTZ

DEMONSTRATIONS AND EXHIBITS.

1. An improvised metal cannula. ROLLIN R. DURANT
2. A new apparatus for the measurement of the psycho-galvanic reflex,
S. R. HATHAWAY
3. The wild flowers of Ohio. WILLIAM KAYSER
4. Map showing distribution of the vegetation of Ohio,
E. N. TRANSEAU AND H. C. SAMPSON
5. Some new mutants in *Drosophila funebris* and *D. hydei*. WARREN P. SPENCER
6. Phomicrographs to illustrate paper No. 9, Medical Sciences Section,
SAMUEL W. CHASE
7. Polychaete ancestry of the insects. Illustrations from unpublished proof of the American Naturalist. L. B. WALTON
8. Cultures of luminous bacteria. (Dark room). O. L. INMAN
9. Cleating and jointing in rocks. CHAS. H. BEHRE, JR.

SPERMATOGENESIS IN BRANCHIPUS VERNALIS.

PART I.

THE TESTIS AND SPERMATOGONIAL DIVISIONS.

R. C. BAKER AND J. A. ROSOF,

Department of Anatomy, Ohio State University

Maturation in *Branchipus* has not apparently been studied since Fries' work on oogenesis in 1910. Concerning either the general or the detailed processes of maturation that should be basic for certain embryological studies, *Branchipus* furnishes excellent laboratory material for the following reasons:

- (1) It is easily available and has a rather wide distribution.
- (2) The mitotic figures illustrating the various stages of maturation are extremely numerous.

The important researches and theoretical postulates produced during the last quarter of the 19th century in the field of Cytology, initiated a series of investigations which resulted in the apparent demonstration of the genetic continuity of chromosomes and their role in heredity.

The discovery of reduction in animals by Van Beneden (1883), and reduction in plants by Strassbouger (1888), coupled with Roux' (1883), statement that chromatin has qualitative differences and that these different qualities are arranged in linear order in the chromosomes, together with Weismans (1887), speculative but fruitful analysis of reduction served as a beginning for the efforts that cytologists have made in the study of reduction.

In the early part of the 20th century the individuality and relationships of chromosomes to heredity was placed on a firmer basis by (Sutton, Montgomery, Wilson, McClung, Welling, Morgan, their students and others). An enormous amount of work has been done, and much as been accomplished toward the first solution of the problem and the main features of the steps involved in reduction of chromosomes has been established. Yet, however, there is some disagreement among cytologists as to the exact method and mechanism of reduction.

This divergence of opinion is greatest in the interpretation of the changes that occur in the chromatin during the early prophase of the meiotic division, for it is at this time that chromosomes conjugate to form bivalent chromosomes. That this conjugation of chromosomes is brought about by a synapsis of homologous pairs of chromosomes is a fact unquestioned by most cytologists today. However, the mechanism and mode of synapse is not too clearly described in any of the evidences produced to prove synapsis of chromosomes. The two views regarding the nature of synapse are, conjugation of chromosomes side by side (parasynapsis) and end to end conjugation (telosynapsis).

The theory of parasynapsis predominates at the present time, although those workers holding to the telosynaptic viewpoint are many in number. This difference in interpretation is due to the difficulty of following chromosome behavior in the early prophase stages preceding the synaptic period, for at this time the chromatin masses are very indistinct in most forms.

It is the purpose of this series of papers to give observations covering the spermatogenesis of *Branchipus vernalis* with special emphasis on the mode of synapse, bouquet formation, chromosomal transformations and formation of spermatozoan chromosome figures.

The material on which this paper No. 1, Spermatogonia, and ensuing articles, No. 2, Primary Spermatocyte, and No. 3, Secondary Spermatocyte, Spermatid and Spermatazoa, are based, was collected from ponds during March and early April, and was identified as *Branchipus vernalis*. This material was fixed in absolute alcohol seven parts, and glacial acetic acid two parts from three and a half to four hours; then washed in four or five changes of absolute alcohol twenty four hours. Only part of the specimen containing the testes was imbedded. Sections were cut five to seven microns in thickness and stained with Heidenhain's haematoxylin. Prior to fixation it is well to keep the specimen in water from twenty-four to thirty-six hours in order that the digestive tract may be freed from silicon.

Acknowledgment of thanks is made to Dr. F. L. Landacre for advice and criticism, and to the Graduate School for financial aid in the reproduction of plates.

THE SPERMATOGENESIS OF *BRANCHIPUS*.

A series of longitudinal sections reveal the testes as paired tubular structures on each side of the digestive tract. They extend from the most caudal portion of the abdomen anteriorly to the thoracic region. A study of a longitudinal section shows that a division of the testis into two parts can be made. (1) The anterior one-fourth or glandular portion and, (2), the posterior three-fourths or germinal portion. Histologically, these two regions are markedly different. The former is characterized by tall, darkly staining columnar cells and the latter by flattened or compressed cells, which form the wall of the tubule. From the ventral side of the testis at the anterior end, the gonoduct is attached. This duct which is glandular in structure, courses ventrally and caudally terminating in the copulatory organ.

The glandular part of the testis secretes a mucoid-like substance which has a vacuolated appearance and stains quite readily. This substance fills the lumen and in it spermatids and spermatozoa are found imbedded in great numbers. The secretion is not confined altogether to the anterior region of the testis but is more abundant there and stains more deeply at that particular region. The germinal part of the testis is concerned in the process of transformation of the basal cells or spermatogonia into the mature free ameboid spermatozoa which are found imbedded in the mucoid material in the lumen of the tubule. The more immature cells are located along the basal part of the tubule and are for the most part spermatogonia. These cells divide and differentiate into more mature forms as they pass from the periphery toward the lumen of the tubule.

A typical cross section of the germinal part of the testicular tubules reveals that each tubule is composed of cells arranged in cysts, (Fig. 14). These cysts vary considerably in number, appearance, location and in the number of cells contained within them. Each of these cysts contain cells which are apparently in the same stage of development. The cysts located more basally contain spermatogonia while those cysts which are nearer the lumen of the tubules contain more differentiated types of cells; some of the cysts contain spermatocytes of the second order, while others contain spermatids or spermatozoa. The cysts containing spermatogonia are large and are the least apparent type. In some cases they are hardly

recognizable as cysts, but usually they are distinguishable. The cysts containing the more differentiated succeeding cellular generations are well defined, smaller, and contain fewer cells.

The inner wall of the tubule lining the lumen is apparently a definite membrane which ruptures at the time of the discharge of the spermatid and spermatozoa into the lumen, leaving an irregular torn area which soon resumes its former condition by the placing of another cyst in the position occupied by the discharged cells.

The lumen of the tubule contains the spermatids and the ameboid spermatozoa which are imbedded in the mucoid-like substance previously mentioned. It is apparent that some of these cells have migrated or have been carried into their present position from a position farther up the tubule.

Superimposed upon the cysts located at the more basal portion of the testicular tubules are a number of very large cells unevenly distributed through the entire germinal portion of the testes. These are Giant cells which are from two to four times the diameter of the ordinary spermatogonia. The cells take a darker stain than do the surrounding ones, and they vary in shape from that of an imperfect sphere to that of an elongated oval form. There is no definite nucleus within these cells, but instead the chromatin is aggregated into several large irregular clumps and many small granules. The larger masses of chromatin have no definite relationship to each other, but are scattered throughout the cells in an irregular manner. Occasionally tripolar spindles are found in these cells. The significance of these cells is uncertain but it is surmised that they are degenerate sex cells. The inference that these cells are degenerate sex cells rather than nurse cells is drawn from the fact that the chromatin is undergoing degeneration and that the cells have no definite relationship to the developing spermatids and spermatozoa.

The examination of a series of sections through the germinal portion of the testis shows an apparent periodicity of function similar to that of the testes of higher forms. This is evidenced by the differences in the cellular content of the germinal portion of the tubules of the testes. As the sections are read consecutively, from one extremity to the other it is noticed that as the more differentiated cells increase in number that the spermatogonia show a corresponding decrease. There are typical regional areas where there is an increase in cellular proliferation.

These regions are separated by portions of the tubules in which there is marked quiescence. The entire picture of this type of tube simulates a wave-like character in which the crest of the wave is the thicker portions of the tubule containing a large number of dividing spermatogonia and primary spermatocytes. There are relatively few mature spermatozoa in this part. The more inactive portions of the tubules between these crests are thin walled containing few spermatogonia and practically no cellular division. The lumen of this part of the tubule is usually packed with spermatozoa.

SPERMATOGENIA.

The spermatogonia of *Branchipus* are located along the periphery of the germinal portion of the tubule throughout its entire extent. The cysts containing the spermatogonia are most apparent and best defined in the regions of more active proliferations. In more inactive regions of the tubule the spermatogonial cysts are not discernible. Instead the cells are arranged in ill defined rows which vary in number from that of a single row to several rows. In the region of activity the cysts are usually large and ill defined but they are nevertheless discernible as cysts. This condition is due to the large number of cells contained within the cysts, the large size of the cysts and the distortion of the boundary of the cysts by the impingement exerted upon them by neighboring cysts which contain cells actively differentiating. The smaller and better defined spermatogonial cysts contain fewer cells which not being closely packed, permits of better inspection of the contained cells since the cells are separated and their contours not distorted by neighboring cells. On the other hand the large and crowded cysts contain cells which are closely packed together and it is only with difficulty that individual cells are recognizable. These cysts are more numerous.

A good criterion for the identification of spermatogonia aside from what has been previously stated is their staining properties. The spermatogonia stain readily and as a result they are darker than the other cellular contents of the testis. The cells other than the spermatogonia and Giant cells have a clear background, the cytoplasm and nucleus appear almost colorless except for the elements that are stained black by the hematoxylin. The spermatogonial cytoplasm and nucleus possess a grey background when colored with this stain. This

greyness of background is quite characteristic in all spermatogonial stages, whether the cells be in resting condition or actively dividing.

The nucleus which occupies almost the entire cell is surrounded by a very narrow rim of grey protoplasm. If the cells are closely crowded then the cytoplasm being compressed appears small in amount. The shape of the nucleus is spherical but at times it may reveal slight variations. The size of the nucleus is not constant. During the resting condition and early prophase, the nucleus is small, being a little larger than one-half the size of a primary spermatocyte. However, the distinction between the spermatogonia and primary spermatocytes are easily made since the nucleus of the former is smaller during early stages and has a different chromatin arrangement in later stages. In addition to this, there is a marked contrast in staining reaction which has been previously stated.

The following description of the behavior of the chromatin in the nucleus of the spermatogonium in *Branchipus* is based upon the study in the transformation of the chromatin in a large series of sections.

A typical spermatogonium in the resting stage reveals the chromatin rather evenly scattered throughout the nucleus with the exception of two or more larger, irregular aggregates. The other chromatin particles vary in size from almost indistinct granules to masses as prominent as the large ones. The chromatin varies in staining properties, some of the granules staining more faintly than others. The nuclear wall is very evident. The cell as well as the contained nucleus is small and somewhat spherical in contour. The size of the resting cell, (Fig. 1) is smaller than any of the ensuing stages. There are only a comparatively few cells in this stage. The chromatin of the nuclei of most of the cells is in the form of different sized aggregates connected with each other by strands exhibiting various degrees of attenuation as the following description reveals.

Gradual changes are seen in the nuclei during the early prophase which results in the formation of definite chromosomes, (Figs. 2, 3, 4, and 5). The first change that is noted is a beginning of a reticulum. This reticulum becomes apparent when the chromatin condenses in certain areas resulting in the formation of larger and fewer aggregates, (Figs. 2 and 3.) The strands which form this reticulum vary in size and form and

are oriented in an indefinite manner. Sometimes, they are long and attenuated—or they may be short and heavy. The chromatin aggregates also show these indefinite characteristics. It is apparent by the inspection of Figures 2, 3, and 4, that the size of the nucleus has increased, and the nuclear membrane is very distinct.

A further change of the chromatin mass continues. The strands of the reticulum contract and separate in certain regions, gradually condensing in an irregular fashion, and form indefinite chromosomes, (Fig. 5). This is the condition of the cells in the majority of the spermatogonial cysts. So numerous are the cells in these cysts that it is only with difficulty that individual cell boundaries are discernible.

The indefinite chromosomes of this phase of development now change in shape and form definitive chromosomes, (Fig. 6). In reference to this figure the remaining attenuated chromatin strands have entirely disappeared. These definite chromosomes are formed by the chromatin becoming equalized in thickness throughout. At this time, homologous chromosomes cannot be identified due to their similarity and their crowded condition. The nuclear membrane disappears and at the same time there is a decrease in the staining property of the cytoplasm resulting in an almost clear background for the late prophase.

By further contraction the individual chromosomes assume their characteristic size and shape, (Figs. 7 and 8). It is quite usual in this stage of development to find individual chromosomes rather equally distributed throughout the cytoplasm of the cell. On account of this scattered condition and the clearness of cytoplasm, these cells are particularly favorable for determining chromosome counts, and relations of individual chromosomes, (Figs. 7, 8, and 9).

There are twenty-three chromosomes in the spermatogonium of *Branchipus*. There is little difficulty in distinguishing homologous pairs, and the accessory chromosome. Figure 13 shows individual chromosomes taken from the cell illustrated in Fig. 7. By reference to Fig. 13, the chromosomes which are arranged according to their similarity, the differences between the unlike chromosomes can be observed. Arranging chromosomes in this manner enables one to detect homologous chromosomes. There are eleven pairs of chromosomes and one chromosome which has no mate (chromosomes of Figs. 7, 8, and 13).

In Figs. 7 and 8, there are some homologous chromosomes which are already paired. Chromosomes D, E, and F, are paired while chromosomes L are in close relationship with each other, (Fig. 7). In Fig. 8, this same condition is observable in three pairs of chromosomes although the chromosomes which revealed a paired condition in Fig. 7, are not all paired in Fig. 8. The only chromosomes paired in both cells are chromosomes F. The fact that the same pairs of homologous chromosomes are not found associated together in every case indicates that this is more of a chance occurrence than the regular procedure in the activity of chromosomes. A significant fact of this association is that the chromosomes involved in individual pairings have the same morphological characteristics.

Following the stage just described, the chromosomes continue to contract and change in shape until they become more or less rounded. At this time, the chromosomes are going on the spindle in preparation of the ensuing division. Fig. 9, shows a polar view of the chromosomes on the spindle. (In this figure there are three enlarged and poorly fixed chromosomes). Chromosomes in the metaphase stage arranged on the spindle are seen in Fig. 10. Here separate chromosomes are observable, but no distinguishable characteristics mark individual chromosomes.

A slightly later stage is represented in Fig. 11. The chromosomes of this particular stage are proceeding to their respective poles. In reference to this figure, two chromosomes which are separated from the main mass of chromosomes are seen. These are the divided accessory chromosomes. The accessory chromosome is not always detached from the main mass of chromatin, for frequently, cells can be found showing no isolated, dividing X chromosome. As the chromosomes near their respective poles, individual chromosomes are no longer distinguishable, but instead they are crowded into a dense mass whose concavity is directed centrally.

Not many anaphase and telophase figures are found. This indicates that the process of division progresses with rapidity in these particular stages. The daughter cells of the spermatogonial division either differentiate into a primary spermatocyte or form other spermatogonia.

CONCLUSION.

- (1) The testes of *Branchipus* is divided into two parts:
 1. the anterior one fourth or glandular portion, and,
 2. the posterior three fourths or germinal portion.
- (2) The germinal cells are arranged in cysts.
- (3) There is a periodicity of function of the testicular tubules as is evidenced by the wave-like areas of cellular proliferation and quiescence.
- (4) There are twenty-three chromosomes in the spermatogonium of *Branchipus vernalis*.
- (5) There is one accessory and eleven pairs of homologous chromosomes.
- (6) In the late prophase some homologous chromosomes become paired. This pairing is more of a chance occurrence rather than the regular behavior in the activity of chromosomes.

BIBLIOGRAPHY.

- BRAUER, A. 1892. Über das Ei von *Branchipus Grubei* von der Bildung bis zur Ablage. Physikalische Abhandlungen der k. Akademie der Wissenschaften z. Berlin, 1892.
- FRIES, WILHELM. 1910. Die Entwicklung der Chromosomen im Ei von *Branchipus Grub.* und der parthenogenetischen Generationen von *Artemia Salina*. Archiv für Zellforschung, Vol. 4, 1910.
- L. W. SHARP. Introduction to Cytology, 2nd edition.
- WILSON. The Cell in Development and Heredity. Third edition. 1922.

EXPLANATION OF PLATE I.

These Figures were made by aid of camera lucida at a magnification of 1250X.

- Fig. 1. A resting spermatogonial cell.
- Fig. 2. An early prophase stage showing the beginning of a reticulum.
- Fig. 3. A less apparent reticulum with the chromatin condensed in areas of the reticulum.
- Fig. 4. Shows the strands of reticulum thickened and separated in some regions. The large mass located centrally represents several condensations of chromatin closely approximated.
- Fig. 5. Shows the formation of indefinite and irregular chromosomes.
- Fig. 6. Late prophase; the nuclear membrane has disappeared and definitive chromosomes are present.
- Fig. 7. The well defined chromosomes show their characteristic size and shape. Homologous pairs are distinguishable and a chromosome count is easily made. Letters E, D, and F, refer to the paired chromosomes. L indicates two homologous chromosomes closely approximated but not paired, X is the accessory chromosome. (See Figure 13).
- Fig. 8. Another cell similar to Figure 7. F indicates homologous chromosomes which are paired. The same chromosomes are paired in Fig. 7. X is the accessory chromosome.
- Fig. 9. A polar view of 23 separate chromosomes.
- Fig. 10. Early metaphase stage.
- Fig. 11. Anaphase stage showing the X chromosome divided and separated from the main chromatin masses.
- Fig. 12. Shows chromosomes approaching their respective poles.
- Fig. 13. Shows chromosomes of Fig. 7, arranged according to morphological similarities. The legend of Figure 7 is the same as that of Figure 13.

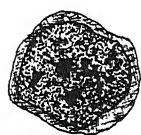


Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6

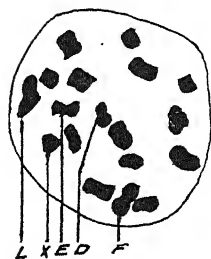


Fig. 7.

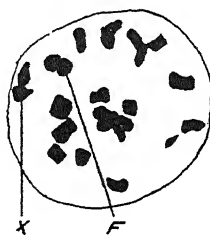


Fig. 8

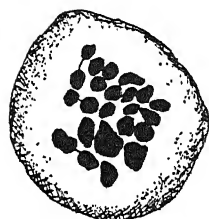


Fig. 9.

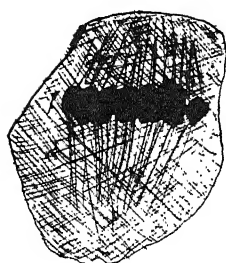


Fig. 10.



Fig. 11. X

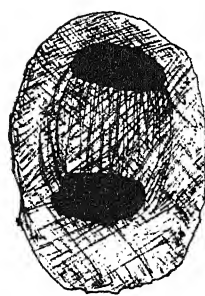


Fig. 12.

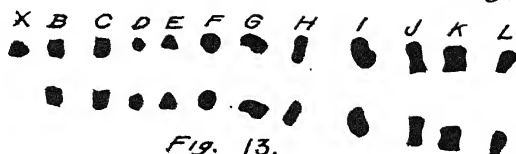


Fig. 13.

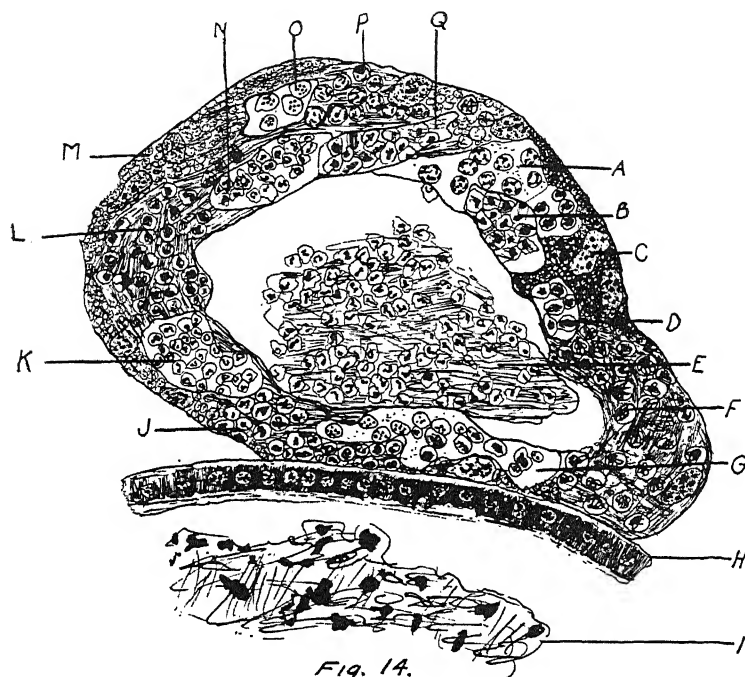


Fig. 14. A camera lucida drawing of a cross section through the germinal portion of a testicular tube $\times 250$, reduced to 125.

- A. A cyst of primary spermatocytes in diakinesis.
- B. A cyst of dividing primary spermatocytes.
- C. A giant cell.
- D. Cyst of dividing primary spermatocytes.
- E. Spermatids and spermatozoa imbedded in the mucoid substance in the lumen.
- F. Primary spermatocytes in bouquet stage.
- G. Stages of primary spermatocyte similar to B and D.
- H. Wall of intestine.
- I. Intestinal contents.
- J. Primary spermatocytes in synapsis.
- K. A cyst containing a few spermatids and numerous spermatozoa.
- L. A cyst of primary spermatocytes emerging from synapsis.
- M. Resting spermatogonia.
- N. A cyst containing few spermatozoa and numerous spermatids.
- O. Primary spermatocytes showing chromosomes going on the spindle.
- P. Primary spermatocytes previous to diakinesis.
- Q. Dividing secondary spermatocytes.

THE PLACE OF THE NATIVE PERSIMMON IN NATURE.

IN RELATION TO OTHER PLANT COMMUNITIES
AND TO CERTAIN ECONOMIC INSECTS.*†

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INTRODUCTION.

The economic value of the native persimmon, *Diospyros virginiana* L., is limited although it finds uses in several different ways. Its real values are in the ebony-like character of its wood, in the nectar produced by the flowers and in the stock it supplies for Japanese persimmon grafting scions. Some mistletoe is collected from the larger trees and sold during the holiday season. The greatest potential value is undoubtedly in the undeveloped and non-commercialized fruits.

The wood is used where a very hard material is necessary as in shuttles, golf stick heads and plane stocks. When the timber was cut along the railroads in the Carolinas large amounts of this wood were used in the mills. The use in recent years, however, is much less, not because it is not as valuable and could not be used in many more ways than formerly, but because of the sub-dominant position it has in nature which limits the supply so that milling for it is not profitable.

A very fine quality of honey is made from the nectar produced by the flowers. It has been rated as the fourth plant in the quantity of nectar produced in the Coastal and Piedmont Sections of North Carolina and probably ranks about the same in South Carolina. In the Mountain Section it is less common but still is one of the important nectar producing plants.

The native persimmon is the common stock now used for grafting of the Japanese persimmon scions. The small seedlings which grow almost everywhere supply an abundance of material for this use.

*A portion of this study was made when the writer was located at N. C. State College and the remainder since going to Clemson College, S. C.

†Contribution 91, from the Department of Zoology and Entomology, Ohio State University.

It is not generally known that the food value of the fruit is next to that of the date and that the flavor of the ripe non-astringent varieties is very excellent. The fruit is used chiefly by negroes, hogs and opossums. The prejudice against the astringent and unripe fruit seems to be extended to all the varieties and even to the Japanese persimmons.

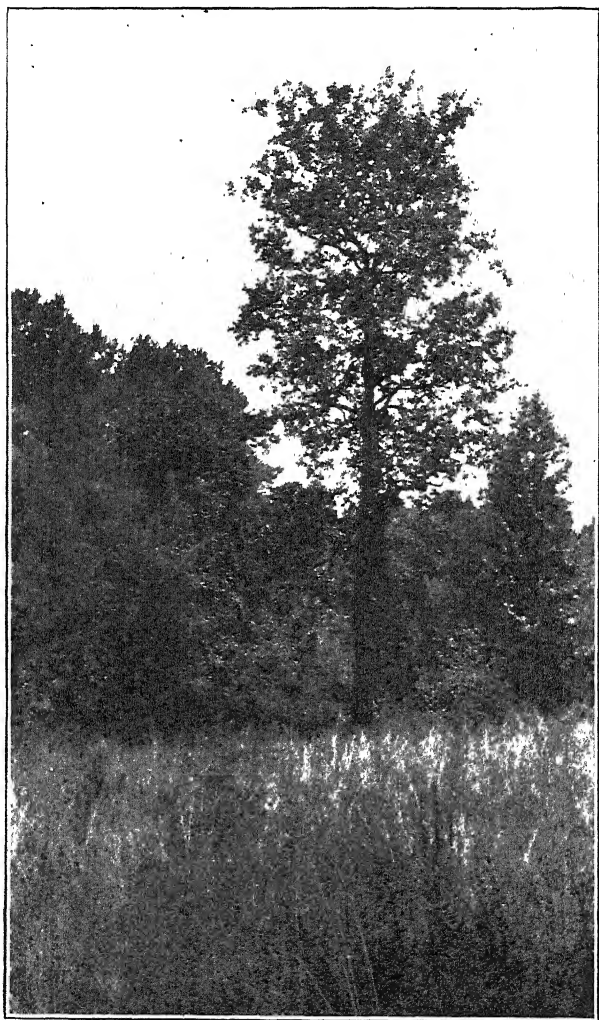


FIGURE 1

RELATION TO OTHER PLANT COMMUNITIES.

The persimmon grows or starts to grow in many diverse habitats but it does not occur in large numbers in any of these after it reaches maturity as do pine, oak and many other trees.

In the rich flood plains of the river valleys the persimmon reaches the maximum size. In the lower Mississippi River valley trees may be found that are 115 feet high, that are 70 or 80 feet to the lowest branches and that have a diameter of six feet or more. In the most favorable habitats of the middle and inner Costal Section of the Carolinas, the tree rarely exceeds 50 or 60 feet in height and a diameter of 18 inches. A few are larger. The usual type of upland tree in the Carolinas seems to be from 30 to 40 feet in height and eight to twelve inches in diameter.

The persimmon is smaller as the elevation increases, so large trees are not common in the Mountain Section. Small trees and shrubs, however, were seen as high as 2500 feet elevation around Ashville, N. C. and at 3500 feet when preceeded by cultivation.

The chief environments are not always the same in different parts of the Carolinas and may be found more variable when studies made in larger areas are reported. In certain areas it is found more commonly on the flood plains or near the margins of swamps as in certain portions of the central and eastern Carolinas. In other areas the upland environments are the most common as in the western part of these states.

The persimmon grows abundantly as shrubby compact growth or as small trees, more or less scattered around the edge of alder swamps. It is sometimes found alone in these situations but red maple (*Acer rubrum* L.) is often found with it. Each species may occur in separate groups spaced about the margin of the alder swamp or they may be very generally mixed together. Sometimes it may be mixed with willow (*Salix* sp?) although when willow occurs in any quantity it usually preceeds it.

In case of a gradual drying or maturing of the alder swamps the persimmon is often found in the alder area sometimes as scattered small trees or even in clumps in the higher areas.

The loblolly pine (*Pinus taeda* L.) and the yellow pine (*Pinus echinata* Mill.) enter as a part of many successions in a large portion of the Carolinas but they are not usually seen

near an alder swamp unless it is near a slope. In that case the pine may grow up to and even into the alders on that side. In case the persimmon has followed the alders on the slope side it will be shaded out by the pine.

On the stream side of the alder swamp willow may succeed the alder, to be followed by persimmon, red maple and sometimes blackberry and smilax for a time. This seems to be one of the situations that allows some trees to attain maximum size since the dominant trees of the flood plain do not always crowd it as much as do the pine from the slope side. Groups of small and medium sized persimmon trees are often seen near the alder swamps that are rapidly drying. Those nearest the swamp are usually the smallest indicating that the swamp is decreasing in size. Grass often starts around these groups of trees and when pasturing follows there is very little then to hinder further growth. But even in these situations the persimmon is only a subdominant species, so in spite of the large numbers that start, but few large trees are ever found and these are not commonly together. In one situation noticed three years ago persimmon was grouped around alder on a stream bank, but both are now dying out under the more vigorous growth of tulip and other deciduous trees.

In some areas of the western Carolinas the persimmon grows around the groups of mountain laurel when it is growing on the banks of rapidly flowing streams. Both deciduous and evergreen trees usually grow very close to these openings, however, so the persimmon never becomes very large.

The way the native persimmon occurs around the swamps containing *Cornus stricta* seems to be very similar to the alder swamp relationship.

The persimmon often enters successions after *Andropogon*, *Erigeron* or *Syntherisma* with pine. However, it is never found with pine after they attain maturity so it appears that the pine growth being more rapid shades the persimmon out. The persimmon is sometimes in these situations without pine, but it is not supposed that it will ever be long before the pine does enter, since a group of them never attains large size.

The persimmon is a common undergrowth in both the loblolly and yellow pine forests, provided the shade be not too dense. However, it gradually dies out as the light requirement increases unless an opening occurs in the pine, in which case, trees of moderate size sometimes develop. If the pine are too

thick and the shade very dense few or no seedlings of the persimmon start. If the pine growth be very open many other shrubs or seedlings (including oaks and Liquidambar) will start and no persimmon will be found.

If a growth of pine, either loblolly or yellow, which has much of the shrubby growth in it be cut, as often occurs, some of the smaller persimmon is usually left. This gives these seedlings an opportunity for growth since they are now unhindered by the pine seedlings which, although they start very soon along with blackberry, *Ergerion* and other weeds, are not eliminative factors for some years. The pine stumps and roots decay rapidly and in a few years the ground may be cleared, very easily, of pine seedlings and rotten stumps. The persimmon meanwhile has grown to some size and is doubtless not all eliminated in the clean up as cultivation proceeds around many trees in fields that have had this history. In case all of the persimmon trees and seedlings are cut in clearing land for cultivation it is a persistent grower coming up year after year from the roots, after all other trees or shrubs are dead. Even fires do not usually kill the roots. Early growth from roots is rapid and unless the grower is persistent these will develop to fruiting trees and thus this serves as another source of the trees of moderate size scattered over cultivated fields.

One of the first trees to be found on much washed and barren areas is the persimmon. It often starts here and grows for years before weeds, *Andropogon* or trees other than the persimmon do, and often attains size large enough to produce fruit.

The persimmon starts in many places other than those noted above. A few of these will be mentioned without any discussion. It is one of the common roadside shrubs and frequently a tree will be found that has developed from this situation. It starts commonly along railroads and even between the ties. It grows abundantly as a shrub on exposed banks as along railroad or highway cuts and fills. Oak, pine, cherry or other seedling may or may not occur along with it.

Small trees or shrubs of the persimmon are sometimes found growing on the banks of small streams, like red maple or tulip, in which case, alder and willow may not have preceded them. It also grows in small numbers successfully and to a large size sometimes along the edge of the narrow strip of

densely wooded area that borders the rivers of North Carolina and South Carolina.

A few places have been observed where the persimmon does not grow or at least it occurs uncommonly. It does not occur in the sand dunes of the eastern coast except in rare cases, where more mesophytic conditions than usual exist. It does not grow commonly as a tree in the Savannahs nor in the long leaf pine areas. In these situations it sometimes occurs as a margin shrub or small tree along roads and improved areas. It is not found in the scrub oak region of the Sand Hill section except as a small margin growth or in low ground where more mesophytic conditions exist and then it rarely becomes very large.

A HOST AND RESERVOIR FOR CERTAIN DESTRUCTIVE INSECTS.

The culture of the Japanese persimmon and the native persimmon for their fruits and the native persimmon as a stock for Japanese persimmon scions has been encouraged, in part, because of their apparent freedom from insect pests. Some studies, made by the writer, of the insects affecting these trees show that both the Japanese persimmon and the native persimmon are less subject to insect damage than the majority of fruit trees but also that several species of insects bear important relationships to them.

The native persimmon is attacked chiefly by leaf eaters, leaf-sucking insects, borers and scale insects. No insect pests of the fruit have been noted in the Carolinas. One gall forming mite is abundant. In this paper, however, only insects that are common on the native persimmon and that bear important relationships to other economic plants are considered. Since very little information has been reported concerning the persimmon psylla, the most characteristic pest of the native persimmon and the Japanese persimmon as well, a brief discussion of it is included.

THE PERSIMMON PSYLLA.

The persimmon psylla, *Trioza diospyri* Ashmead, (a Homopterous sucking insect), attacks the native persimmon and the Japanese persimmon chiefly when the insect is in the nymphal stage. The feeding of the adults rarely causes apparent damage. The largest numbers of the insects and the maximum

damage occur in the spring and summer when the leaves are young and growing, before control by the parasites and predators has become effective and while the female psyllas are laying the largest number of eggs. During late summer and fall one rarely finds this insect in numbers on the Japanese persimmon. It also becomes most uncommon on the native persimmon. At this time, it is found only on the young shrubby growth where some of the leaves are still young and growing. The injury on larger trees where growth is not succulent is never great.

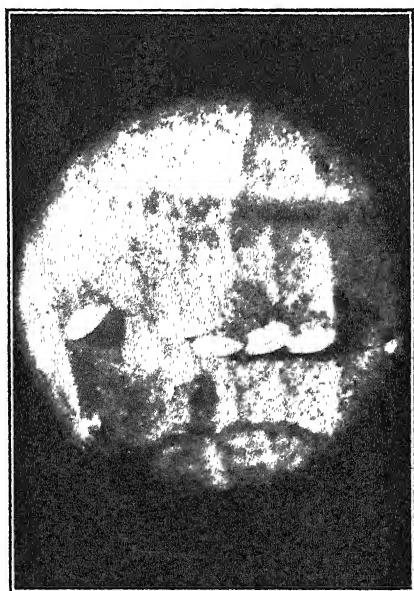


FIGURE 2

Development and Description.

The persimmon psylla, occurs in three different stages: i.e., the egg (Fig. 2), the nymph or developing young (Fig. 3), and the adult. The latter, when mature, is a shiny black insect about 2.5 millimeters long with transparent wings raised vertically over its body when at rest and having one ivory white line on either side of the abdomen anteriorally. They appear somewhat like graceful aphids but, unlike them, have the habit of jumping quickly.

Females that emerged in the insectary on known dates lived from 6 to 39 days with an average of 16.8 days. They laid eggs in from two to nine days after emergence. The maximum number of eggs laid by one female on test was 1,173. The average number of eggs laid by the females of an early generation was 230.5; by a later generation, 173.6 and by a mid-summer generation 37.

The preoviposition period of 311 females averaged 5 days. Mating usually occurs a number of times at varied intervals beginning within a day or two after the females emerged. The male walks up beside the female, the posterior end of the abdomen curves around to the female and copulation takes place while they stand beside each other.

The elongate-ovate eggs of the persimmon psylla are found lying flat on the succulent growth of the persimmon. They are about .01 inch in length with the larger end curved down and attached while a short pointed portion curves away from the support at the smaller end. The eggs are pale white, turning to yellow or brownish yellow before hatching. They are laid singly, usually rather uniformly arranged in rows along the margin of the leaf, on the surface of the leaf, or on the petiole or stem. They may also be found very generally scattered over these areas. Sometimes they are found scattered or grouped in the axils of the leaves or around dormant buds.

The period of incubation of 36,770 eggs laid by ninety-nine females of three generations during the period from May 28, 1926 to July 16, 1926 averaged 8.6 days with a maximum of 15 days and a minimum of 4 days.

In the early stages the nymphs are minute, elongate, rounded insects usually clear white in color (occasionally a brownish red) with very few spines. The older nymphs are much flattened and strongly fringed (Fig. 3). They cling very tightly to the leaf in such a way that it is very difficult for other insects to attack the soft ventral surface of the abdomen. In the last instar the nymphs assume a bluish color. They are usually protected inside folds of the leaves.

The nymphs excrete a watery fluid, as do aphids, which is enclosed in a thin membrane. The mass is cylindrical in form when issuing from the psylla nymphs and may remain so, or it may coil somewhat as a watch spring, or break up into globular masses. These excretions are gradually shaken from the folds of the leaves, where many nymphs develop, by wind

or other disturbances. When the nymphs are in exposed positions they fall directly to the ground. The leaves are thus not soiled by the excretions and fungous diseases have not the opportunity to grow as they do in excretions from aphids. It seems that this adaptation may be correlated with the formation of the leaf rolls. Were it not for this adaptation

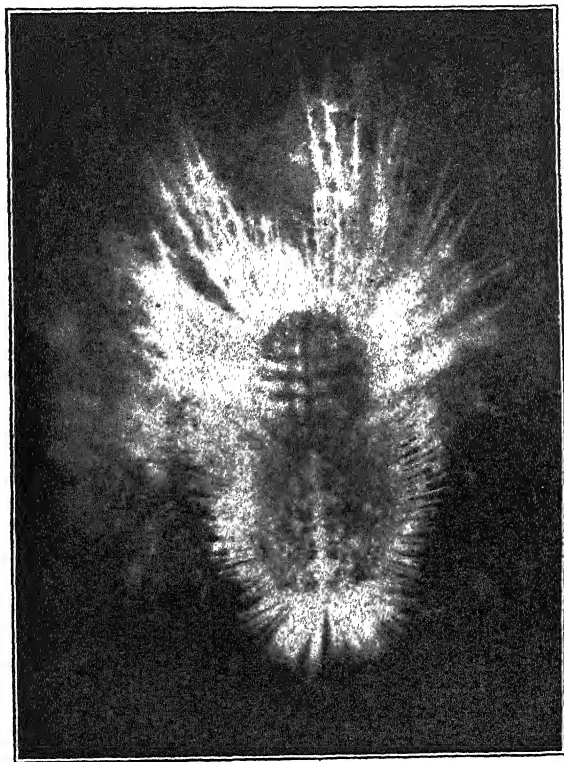


FIGURE 3

these leaf rolls would be filled with a mass of sweetened, sticky excretions that would probably very soon render them unfit for use by the insect.

When the nymphs are ready to transform they crawl to an exposed surface, usually on the leaves, and the adult insect emerges through a dorsal longitudinal slit in the head and thorax. The newly emerged adult is greenish in color.

Habits and Damage.

The nymphs may be found on practically all the growing leaves of the native and the Japanese persimmon since the shape of these leaves can be modified. One generation of nymphs is usually all that develops on one leaf as the leaves are then older and are not modified by the insect.

The nymphs are usually found on the lower surface of the growing leaves of the native persimmon near the margin with the edge folded or rolled more or less tightly over them (Fig. 4). Sometimes they occur on the upper surface of the leaves with the edges turned up over them. A few are found on the upper surface of the leaves near the tip of the mid-veins with each side of the leaves raised vertically and tightly enclosing the insects. Occasionally they are found scattered over the leaves generally. Some cling tightly to the sides of the veins.

On the Japanese persimmon these insects rarely form folds but they do produce indentations or pits on the lower surface of the leaves. They do not stay on the Japanese persimmon as long each year as they do on the native persimmon.

Most of the damage to the native persimmon is in the stunting of growth because most of the leaf folds straighten and recover, very largely, after the nymphs transform to adults. Some permanent mechanical injury occurs sometimes when the number of nymphs in one fold is very great. At times the leaves are so severely injured they curl, wilt, die and fall from the tree. A few cases have been seen where the growing tips of the branches were killed.

The damage caused by this pest to the Japanese persimmon is also chiefly in the stunting of growth since the change the insect causes to the leaves is usually slight and recovery is rapid after they become adults.

Natural Control.

The persimmon psylla is preyed upon by the larvæ of the syrphid, *Allograpta obliqua* Say, which usually pry up the body of the nymphs, puncture the ventral abdominal surface and suck the body fluids. This syrphid has been very abundant the last few years during the early summer.

The control of the nymphs of the persimmon psylla by an internal parasite, *Psyllaephagus trioziphagus* (How.), becomes highly effective during the late summer. This parasite, how-

ever, is rarely found during the early part of the season. Several species of ladybird beetles (larvæ and adults) are also commonly predaceous on the nymphs. Of these, *Hippodamia convergens* Guer, and the one usually called *Megilla maculata* DeGeer, are the most common.

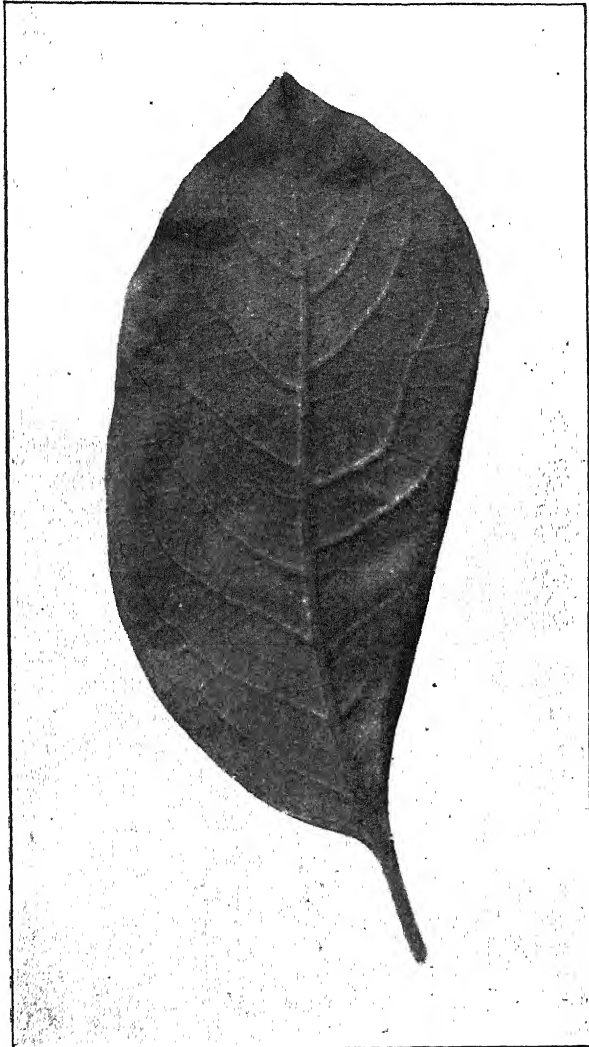


FIGURE 4

Artificial Control.

Only partial control of the persimmon psylla has been secured by using nicotine sulfate sprays because it comes in contact with very few of the nymphs that are protected in the folds of the leaves. Some growers, however, report it as being fairly satisfactory since it kills many of the eggs. The eggs are usually laid on the exposed surfaces. Six percent nicotine sulfate with lime hydrate as a dust and Cyanogas "S" dust (one half calcium cyanide and one-half sulfur) have both given better control of the nymphs and adults in preliminary tests than have sprays of nicotine sulfate.

THE TWIG GIRDLER.

The twig girdler, *Oncideres cingulata* Say, is a severe menace to the pecan industry in many parts of the South because it girdles large numbers of fruited branches before the nuts are ripe. The girdled branches usually break from the tree soon after they are girdled. Even in pecan orchards where the twig girdler is controlled by destroying the girdled branches of the pecan trees which contain eggs or larvæ or both of the pests, the trees may be subject to the attack of the adults, each fall, which have matured from severed branches of near-by native persimmon trees.

When the branches are girdled it results in numerous twigs growing out near the girdled end thus giving a "bunched" effect. This is common on trees of all sizes.

In the experience of the writer, judging from the comparative number of twigs girdled on the several host plants in the Carolinas, the persimmon appears to be the favorite host plant of the pest. Because of this fact, the native persimmon serves as a tremendous reservoir for the twig girdler as a source of infestation for pecan orchards. This makes it necessary to burn the girdled branches of near-by persimmon trees as well as those of the pecan and hickory in the control of this insect. Persimmon trees having no value could be destroyed and this control measure would not have to be repeated each year.

The twig girdler is not abundant and a menace in all areas where either the pecan or the persimmon grow.

OTHER INSECTS.

The San Jose scale is the most common scale of economic importance that occurs on the native persimmon. Infestations are very unusual, however, unless the trees are near orchards, where San Jose scale is common. Heavy infestations and severe damage have been caused by the webworm, identified as the summer brood of *Hyphantria cunea* Drury, during each year in the area under observation.

There are other insects that are common on the native persimmon. Some of these attack no other hosts while others are more or less general in their feeding habits. These will be included in another report.

SUMMARY.

1. The persimmon grows or starts to grow in many habitats in the Carolinas but does not occur in large numbers in any of these after maturity. This is because of the subdominant place it has in relation to other trees.

2. It starts to grow as a shrub or tree, in the margin of alder swamps, in successions after *Andropogon*, *Erigerion*, or *Syntherisma*, as an undergrowth in certain forests, in open and barren fields and in many other places but it is usually shaded out, for the most part, by pine and deciduous trees.

3. The persimmon is a host and reservoir for certain insects of economic importance in the Carolinas.

4. Persimmon psylla nymphs suck the juices from the leaves of both the native and Japanese persimmon and often cause folds and rolls in leaves of the native persimmon, and indentations or pits on the lower surface of the leaves of the Japanese persimmon.

5. Soapy nicotine sulfate solutions gave some control of the egg stage while nicotine sulfate with lime hydrate as a dust and Cyanogas "S" dusting mixture were more effective in the control of nymph and adult stages.

6. Persimmon is a host and the chief reservoir for the twig girdler, in many sections where pecans are grown, and thus serves as a menace to this industry. It is an important host of the webworm and is occasionally infested with San Jose scale.

THE CELLOIDIN INJECTION OF BLOOD VESSELS.*

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Leonardo da Vinci, living in the 15th century, was, so far as we are able to determine, the first scientist to use injection methods to demonstrate the blood vessels. Garrison (1) illustrates a drawing from Leonardo's Quaderni in which the ramifications of the femoral artery give one the impression of an injection. Since this pioneer work anatomists have, from time to time, used this method for the demonstration of not only the larger blood vessels but also to demonstrate the capillary circulation. Among the more recent work should be mentioned that of, Huber (2) on the circulation of the kidney, Gross and Kugel (3) on the circulation of the heart valves, and that of Hinman and his coworkers (4) on the changes in the circulation in the hydronephrotic kidney. After all this most excellent work, we hesitate to add another paper on the dry details of technique, but because of the cordial reception which has been given to demonstrations which have been made at various scientific meetings of specimens prepared by celloidin injection of the human kidney, we feel that the technique may be of use to other workers in the same or allied fields of biology. The method as given here has been developed so as to give consistent results on the human kidney, but by slight modification of the strength of celloidin and the pressure will give equally good results on the kidney or other organs from the lower animals.

Method: The kidney is removed from the body as soon after death as possible, but good results may be secured as long as 30 hours after death. Particular care should be taken in sectioning the renal artery. It should by preference, be cut with a piece of aorta attached, so that a large canula may be inserted and also that it may be secured at a point at least one-half inch proximal to the point of primary division. (It has been our experience that a considerable number of human kidneys show an anomalous vessel arising from the main stem renal artery just distal to its origin from the aorta and entering the lower pole of the kidney directly). Further, one should be careful to remove

*Read before the Medical Science Section, Ohio Academy of Science, April 9, 1926.

the kidney with the perirenal tissue attached since the capsular branches of the renal artery in the human kidney are of considerable size and will give trouble in ligation later if a goodly portion of the tissue about the kidney is not included. As soon as possible after its removal from the body the kidney should be taken to the laboratory for the actual injection. A canula is tied into the renal artery and connected to the city water supply, in this manner allowing water to flow through the kidney from the water lines until 125 to 150 gallons of water are forced through the capillary bed of the organ. This in our experience is most satisfactorily accomplished under a head of 600 mm. of Hg. flowing for

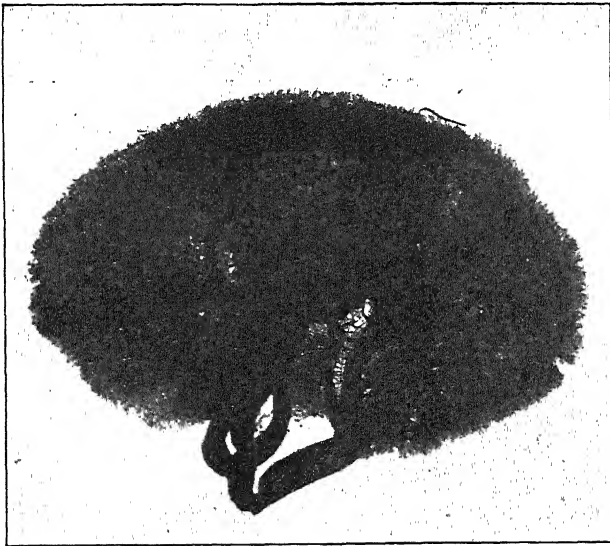


FIGURE 1

24 hours. (Special clot dissolvers and vaso-dilators as used by some authors have not shown any advantage over this method in our hands). After this thorough washing the kidney is placed in a vessel and covered with water and the canula connected to the injection apparatus. A current of air is passed through the arterial tree and as the kidney is submerged in water, all leaks are readily detected and ligated. This is important since to maintain the required pressure of injection later and to avoid the loss of considerable quantities of celloidin, the arterial tree must be a closed system. When one is satisfied that all leaks are secured, a bottle of thin celloidin is placed in the circuit and a clamp placed on the rubber tube leading to the canula. By air pressure the pressure in the bottle of celloidin is raised to 600 mm. of Hg., at which time the clamp is suddenly released and the full pressure is allowed to enter the kidney vessels at once. This is important since a gradual raising of the pressure will not give a perfect injection. If the celloidin is of the

correct strength, it will pass into the glomeruli but will not pass beyond because of its viscosity. The thin celloidin injection is maintained for two to six hours when it is replaced by the thick celloidin which is injected under a constant head of 600 mm. of Hg. for twenty-four hours. During the entire procedure the organ is kept immersed in water. For a source of pressure we use tanks of compressed carbon dioxide to which a reducing valve is attached. In this manner a constant pressure may be maintained for hours. After twenty-four hours the canula is disconnected and the capsule and perirenal tissue stripped from the kidney. The kidney is then placed in a 75 per cent solution of hydrochloric acid which in 24 to 48 hours will so completely digest the soft parts that a gentle stream of water will remove them, leaving a celloidin cast of the blood vessels.



FIGURE 2

The celloidin solutions used in the injections are:

THIN CELLOIDIN.

Paraloidin.....	2.75 gms.
Camphor.....	2.0 gms.
Acetone.....	100.0 cc.

THICK CELLOIDIN.

Paraloidin.....	10.0 gms.
Camphor.....	8.0 gms.
Acetone.....	100.0 cc.

The celloidin may be colored by various fat soluble dyes. We have used Scharlet R for red and Methyl green for blue. If it is desired to inject the veins a similar technique is used except that 200 mm.

of Hg. is used instead of 600 mm. For the pelvis we use 20 per cent celloidin and 15 per cent camphor in acetone and inject under 60 to 75 mm. of Hg.

The accompanying figures illustrate both the completeness and the detail of injection that may be secured by this method.

BIBLIOGRAPHY.

1. GARRISON—Anatomic illustration before Vesalius. Paul B. Hoeber, New York. 1926.
 2. HUBER—Amer. Jour. Anat. 6, 400. 1906.
 3. GROSS AND KUGEL—Amer. Heart Jour., 1, 304. 1926.
 4. HINMAN MORRISON, AND LEE-BROWN—Jour. Amer. Med. Assn., 81, 177. 1926.
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CISSIA MITCHELLI (FRENCH) FOUND IN OHIO, WITH NOTES ON ITS HABITS.

LEPIDOPTERA—SATYRIDÆ.

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Cleveland Museum of Natural History.

Cissia mitchelli was first described in 1889, by Professor French, from specimens collected from Cass County, Michigan, by Professor J. N. Mitchell. Professor Mitchell also believed that he had observed it in central Michigan. The first specimens were collected in a dry upland meadow, near a wet meadow and marsh, but later Professor Mitchell found them much more abundant in the marshy area. He writes, "It flies low, for short distances, in a weakly manner, and is best started by beating up, or by walking rapidly and noisily through the grass. * * * If there is more than one brood of *Mitchelli* in a season, the last one begins to fly July 1st. I have taken it from July 1st-10th. As far as I can tell it comes in quickly and goes off the field rather abruptly after a short period of life". On July 10, 1890, Mr. Charles W. Johnson captured one specimen near Dover, Morris County, New Jersey.

On July 4th, 1925, I captured six specimens of this rare butterfly in a swampy meadow on the edge of a peat swamp, near Streetsboro, Portage County, Ohio. The insect was very abundant, but specimens in fair or good condition were exceedingly hard to find. About two weeks later when I again had the opportunity of visiting this spot not a specimen was observed.

In 1926; on July 4th, I visited the spot where I had collected and seen this butterfly the previous year. There wasn't an individual to be found. Six days later, July 10th, I returned and found the insect plentiful, most of them in very good condition showing that the adults had just matured. I did not have an opportunity to return until the 24th of July, at which time only a single specimen, a female, was seen.

Cissia mitchelli appears to be confined to an open swampy peat meadow about an acre in extent. The vegetation of this area is low, although surrounding this spot, it becomes rank and tall. The dominant growth is a swamp grass, Virginia chain-fern (*Anchistia virginica*), and bedstraw (*Galium boreale*). Scattered throughout the area are dwarf specimens of the common blue wood aster (*Aster cordifolius*), and the showy ladies'-slipper (*Cypripedium reginæ*). Tamarack, maple, and choke cherry trees partly hem in this spot. The rest is bordered on one side by cat-tails which are gradually encroaching, and on the other side by a rank growth of swamp grass and weeds.

Cissia mitchelli is very easily captured. It rests quietly on a blade of grass or a weed stem, usually with the head down, until approached to within three or four feet. The butterfly will flutter up with a weak irregular flight, typical of the satyrids; rising seldom more than four or five feet from the ground, and settle again about ten feet away. The female is slightly stronger in flight than the male. At no time did I observe any protracted flight; moreover the males showed little vigor or tenacity when fighting. I observed no insect either feeding or ovipositing.

Associated with this butterfly were specimens of *Satyrodes canthus* and *Cercyonis alope*. The most striking feature of the habits of this butterfly is its confinement to one small area. Although there are many similar spots throughout this several hundred acre peat swamp, no other place yielded any specimens of this insect.

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THE OBSERVER: AN INSTRUMENT OF PRECISION.

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The development of methods and technique in measurement is fundamental to the progress of any science. A science, like physics, in which these methods have been developed to a high degree is referred to as an *exact science*. The tools of an exact science are referred to as *instruments of precision*. Mathematical treatment of the data of scientific observation gives the scientist various measures of the degree of precision obtained. It must always be kept in mind, however, that the idea of "exact" or of "precision" is relative rather than absolute.

In practical life as well as in making scientific observations, we are constantly making use of instruments of precision. I look at my watch to see what time it is. Compared with the dollar watch I carried recently while this watch was being cleaned, my own watch is an instrument of precision. Compared with my watch, the chronometer in the window of the shop by which I set my watch last week is an instrument of precision, and yet this chronometer is corrected from time to time on the basis of reports telegraphed from the U. S. Naval Observatory at Washington, where other instruments of precision,—transits, micrometers, verniers, and the like, are used to determine the correct time. Thus we see that precision is a relative rather than an absolute matter. To take an example from Merriam's "Method of Least Squares", a certain angle was measured by the same observer with three different instruments, a theodolite, a sextant, and a transit. Four observations with the theodolite gave a result of $6^{\circ}17'5''$, with a probable error of 1.4". Five observations with a sextant gave $6^{\circ}17'12''$, with a probable error of 5.8". Six observations with the

transit gave $6^{\circ}17'0''$ with a probable error of $23.3''$. The true value of the angle is certainly in the neighborhood of $6^{\circ}17'$, since the results of all three instruments agree in this. But the limits between which the true result may be expected to lie vary with the three instruments. The true value as determined by the theodolite, the most accurate of the three, may, with a probability greater than one-half, be considered to lie between the values of $6^{\circ}17'5''-1.4''$ and $6^{\circ}17'5''+1.4''$, that is, between $6^{\circ}17'3.6''$ and $6^{\circ}17'17.8''$; and the transit, the least accurate of all, gives limiting values of $6^{\circ}16'36.7''$ and $6^{\circ}17'23.3''$. These are all instruments of precision and yet one has a higher degree of precision than another and in no case is the precision absolute.

Now when we consider the methods used in astronomy, physics, or any other of these so-called exact sciences we find that instruments of precision play an important part in them all, both in the observation of natural phenomena and in the development of experimental technique, as well as in the standardization or correction of other instruments. We realize further that in any of these methods the observer, the man who looks through the telescope or reads the thermometer, plays an important part. In fact, for the purposes of science, the observer himself is an instrument of precision. It is, therefore, interesting to the worker in any field of science to make a study of this useful and necessary instrument. The study of this human instrument is a major problem in the science of psychology.

The development of modern psychology has been characterized by a breaking away from the psychology of the past, which was based deductively upon a speculative philosophy, and by the foundation of a new experimental science, bringing to its service many of the instruments and methods of the older sciences, and inventing instruments and methods of its own. This modern movement is usually dated from the year 1878, when Wundt (1832-1916), then holding the chair of philosophy at Leipzig, founded at that university the first laboratory of experimental psychology. Wundt had begun his career as a professor of physiology at Heidelberg and brought to the new science of psychology the data and experimental procedure of this older science. In the nearly fifty years since that time, psychology has been developed as an experimental science which can no more stand by itself without dependence upon physiology than modern physiology can exist without chemistry.

Though the object of psychology continued to be defined as the study of the processes of consciousness, the principle came to be universally admitted that nothing happens in consciousness which is not conditioned by certain physiological processes. If one accepts the definition of psychology given by the more recent behavioristic school that "psychology is the science of the reaction of the individual to the stimuli to which his environment subjects him", this notion of the observer as an instrument of precision is still further emphasized.

Accepting this definition, we find that we are interested in an individual human being, not as a mind or soul made up of or possessing certain faculties such as cognition, will, and reason, but as an organism that reacts in a certain manner in a certain situation. We find that this reaction is determined by the arousal of certain physiological processes involving particularly the nervous system of the organism, and we have consequently seen the development of a psychology of the lower animals and of the human infant as well as an objective study of the human adult. It matters little for our purposes whether we consider only the reactions of the observer in a scientific experiment, or also make reference to his conscious states, and the terms "perceive" and "perception" will be used here without any necessary implication of one point of view or the other. In the sense that an instrument of precision is a *mechanism*, it may appear that the argument is in favor of a behavioristic interpretation, but the discussion is just as, or perhaps even more, pertinent to the methods of scientific observation if one makes his interpretations from the standpoint of psychophysical parallelism or interactionism.

That branch of psychology which seeks to determine the functional relation between the physical processes which we call stimuli and the reactions or mental processes of the organism is called *psychophysics*. For example, I ask someone to tell me which of the two weights is the heavier. If one of these weighs 100 grams and the other 120 grams he will very readily select the heavier, whereas, if one of them weighs 100 grams and the other 101 grams, he is very likely to tell me that the two are equal. Now the first weights act as stimuli giving rise to certain sensory responses or perceptions of weight due to strain upon the muscles of his arm which are richly supplied with sensory nerve endings. Certain neural and brain processes are involved. The second case is similar, but in the first case the

weights are perceived as different and the judgment "heavier" is given, and in the other "equal", by which we imply that his perception of weight is not different from that aroused by the standard weight with which it is compared. We are interested in determining under what conditions his reactions to the weights are the same and under what conditions they are different. We seek further to formulate some mathematical statement which will generalize our findings, just as the astronomer or physicist derives his mathematical formulae.

We have here the concept of the sensitivity of the observer just as we speak of the sensitivity of a chemical balance which is used in comparing a given object with certain standard weights or masses. Closely connected with this idea is the concept of the *threshold*, a term introduced into psychology by Herbart in 1811. It is perfectly obvious that, in order to be perceived at all, a stimulus must have a certain intensity. Suppose we are looking at the stars on a clear moonless night. We can see stars up to the first, second, and third magnitude, and if our eyesight is keen, up to the sixth magnitude. But we know from using a telescope that there are thousands of stars too faint to be seen by the unaided eye. The intensity of light from one of these is not great enough to arouse a sensory response. In other words, its intensity is below the threshold. The threshold may be defined, therefore, as that value of the stimulus which is just sufficient to produce a sensory response, less values producing no response.

It is clear that the value of this threshold for any given kind of stimulus may vary for different individuals and in the case of vision, for example, for the two eyes, and for different parts of the retina of the same eye, in the same individual. Its value will also vary with varying conditions of attention, expectation, practice, and fatigue. We see at once that the value of this absolute threshold of intensity is an index of the sensitivity of the observer. The lower the threshold, the greater his sensitivity; and the higher this threshold, the less his sensitivity.

To take another illustration from astronomy. Two observers, A and B, are gazing at a small constellation. A is a trained astronomer, while B is an amateur. A sees nine stars in the constellation, while B sees only seven. A makes a drawing of the stars in this constellation and shows B where the two stars which the latter does not see should appear, or he allows

him to observe them through a good field glass. He further shows B how to focus his eyes on a point a little to one side of the position where the stars are to be seen, as for dim light the center of vision is not the most sensitive portion of the retina. These changes in the method of observation, this practice, and attentive expectation act to lower B's threshold and he finds that he can now see nine stars in the constellation just as A does. His absolute threshold has been lowered and his sensitivity increased.

We sometimes speak of an upper threshold or limit of sensibility in contrast with that just described which is designated as the lower threshold. The upper threshold is that stimulus value beyond which there is no sensory response. Both are well illustrated in the case of tones produced by vibrating bodies or air columns. Some observers have claimed to hear as a tone the vibrations of a tuning fork vibrating sixteen times per second, but for most of us this lower limit is about thirty-two vibrations per second. On the other hand, as will be observed if we listen to a Galton whistle, we may shorten a vibrating air column, making the pitch higher and higher, until we pass the upper limit of sensitivity and no tone is perceived. This upper threshold for pitch is about 36,000 vibrations per second.

In light waves we find a similar phenomenon. If a beam of sunlight is diffracted by a prism or grating and thrown on a screen, we get a spectrum, but only a part of this will be visible to the human eye. We see violet, blue, green, yellow, orange, red; but it can be easily demonstrated in the physics laboratory that beyond the violet are the ultra-violet rays and beyond the red are the infra-red rays. The former are beyond the upper and the latter below the lower limit of sensitivity or wave length threshold and the latter below the lower limit of sensitivity or wave length threshold for the human retina.

The lower threshold values in animals are often quite different from those observed in the human species. Dogs have a remarkable sensitivity to olfactory stimuli. Romanes tells the story of a dog whose olfactory sensitivity was tested in the following manner. The dog's master walked nearly across a large field and turned abruptly to the right. He was closely followed by twenty-four men, each of whom tried to step exactly in the footsteps of the man in front of him. At the place where the owner of the dog turned to the right, the first

man following turned to the left, the second to the right and so alternately until twelve had followed to the right and the other twelve had gone to the left, each stepping in the other's tracks as before. A short time afterward, the dog was set on his master's trail, which he followed rapidly to the turning point. Here he ran past, but returned to "pick up the scent". This he did readily, following his master's trail without hesitation.

The problems of the psychophysicist are not limited to the determination of the limits of sensitivity—these upper and lower thresholds. Lying between these limits are series of stimuli all of which may give rise to parallel series of sensory responses varying in quality, intensity, and duration. The stimuli consist of some form of energy—kinetic energy, light, heat, etc.—which may be measured in terms of physical units. This light is 32 candle power, that is 16; this is a weight of 100 grams, that of 120, etc. Roughly speaking, the stimulus intensity series and the response intensity series are parallel. Two weights are heavier than one. A 32-candle-power light is brighter than one of 16 candle power. So true is this parallelism that our language is often confusing. We can not be certain which series is meant when some one says that "one sound is louder than another." The statement may refer to response intensity or to the intensity of the sound waves of the stimulus, or to both.

In spite of this rough parallelism, it can easily be shown that the response intensities may be indistinguishable, whereas the stimuli are clearly different, or that stimuli of equal intensities may be perceived as different. It is, therefore, the problem of psychophysics to study the relation which does exist between these two series.

This brings us to the concept of the *difference threshold*. In lifting two weights we may not be able to discriminate between 101 grams and 100 grams, the judgment "equal" being given. It is obvious that if we gradually add to the 101 gram weight we shall finally get a weight which will be judged "heavier" than our 100 gram weight. If such a weight is 103 grams, our difference threshold in the direction of increase is 3 grams. That is, a difference of 3 grams in stimulus intensity is just sufficient to produce discrimination. In a similar way by comparing weights of 99, 98, 97 grams, etc., with our original standard weight of 100 we come to a weight which is just perceptibly lighter than our standard. If this is 98 grams, our

difference threshold in the direction of decrease is 2 grams. A more sensitive subject might distinguish 102 and 99 grams from 100. His difference thresholds in this case would be therefore 2 grams in the direction of increase and 1 gram in the direction of decrease. The interval between these two difference thresholds is known as the *interval of uncertainty* since the person lifting the weights included in this interval can not judge better than by chance whether the comparison weight is heavier or lighter than the standard.

These measures of difference have been called "just perceptible differences." By taking account of these just perceptible differences in any given stimulus scale, either of quality, intensity, duration, or extent, we may arrange stimulus series which are paralleled by series of just distinguishable sensory responses or perceptions. The difference threshold may, therefore, be defined as the smallest different in two stimuli such that the two will be discriminated better than by chance. As it is a matter of relative stimulus value it may be stated in terms of the units of stimulus value or as a percentage. In this sense the difference threshold is comparable to the concept of probable error, the interval of uncertainty corresponding to the interval between the plus and the minus probable error.

The series of just distinguishable sensory responses are often very extensive. For example, in the series in the octave between A¹ with 435 vibrations per second and A¹¹ with 870, there are over 1200 tones which can be discriminated or are "just noticeably different", in the practiced ear of a musician.

It will make the concept of the lower threshold, or stimulus *limen* and that of the difference threshold, or difference *limen* clearer to mention a few analogies. The first is that of the tangent galvanometer first suggested by Delboeuf. (1831-1896).

The tangent galvanometer is an instrument for measuring an electric current by means of a magnetic needle suspended in the field of a coil of wire through which the current to be measured is passed. The angular deflection of the magnetic needle is observed and read from a graduated scale. It is found that the greater the current passed through the coil, the greater the total deflection of the needle from its original position. It is further observed that the amount of angular deflection due to a given increase in current is not, however, directly proportional to the increase in current, these increases producing less and less additional deflection the farther the

needle swings from the original position. Moreover, no current can be made strong enough to cause a deflection of 90° . It has been found that the current intensity is directly proportional to the tangent of the angle of deflection. The instrument is, therefore, called a tangent galvanometer.

If we observe the action of this instrument as our electric current is gradually increased we find an interesting phenomenon which is analogous to that observed in our stimulus-response series. First we note that the current has to be of a certain strength before the inertia of the needle and the torsive resistance of the suspension fiber are overcome and any deflection at all is noted. This corresponds to our lower limit of sensibility, our lower stimulus threshold. If a finer needle with a gossamer suspension fiber is used, this resistance may be reduced and our instrument rendered more sensitive, i. e. its stimulus threshold has been lowered.

The analogy can be carried still further, in that, when the needle is held at any given angle by a current of a certain strength, a further deflection will not take place, for the reasons mentioned above; until a certain amount of increase of current has been made which can overcome these resistances. This necessary increase is analogous to the difference threshold and may be greater or less according to the sensitivity of the instrument and to the position of the needle.

Another convenient analogy may be found in the chemical balance. Here scale pans are mounted at the two ends of a horizontal beam swinging freely in the vertical plane on an axis perpendicular to this plane of rotation. If these pans are in equilibrium a tiny bit of dust falling on one of them will not cause a tilting of the beam. But if dust should be allowed to accumulate on one of the pans the resistance due to inertia and friction would finally be overcome and this scale pan would drop and the apparent equilibrium would be destroyed. The mass of the dust necessary to effect this disturbance of equilibrium may be compared to the lower threshold of sensibility, the just perceptible stimulus already mentioned. If the balance were made more sensitive by reducing the friction, or the mass of the pans, or by increasing the length of the beam, this equilibrium would be disturbed by a smaller amount of dust, i. e., its stimulus threshold would be lowered.

If two equal masses are placed on these scale pans in their previous condition of equilibrium they will balance one another

and we have again a condition of equilibrium. To disturb this again it is necessary to add an appreciable amount to one of the pans. This is comparable to the difference threshold or just perceptible difference.

A third illustration may be found in observing the elasticity of a rubber band. It is necessary to exert a certain amount of force upon it before it will stretch at all. Again we have our lower threshold or limit of sensibility. After it has begun to stretch, relative changes in length will be proportional to the force exerted upon it. If held in a stretched position, however, an appreciable increase in the force exerted must be made before it will stretch further. Again we have our difference threshold. If force enough is applied, the limit of elasticity will be reached, the rubber band will break, and we have an analogy to our upper threshold or upper limit of sensitivity.

The human subject may be compared to such an instrument as the chemical balance. A weight must be of a certain intensity before it is perceived at all. A weight held in the other hand must have a "just noticeable difference" added to it before it is perceived as heavier. Here we have the stimulus threshold or limit of sensitivity and the threshold of difference.

These thresholds may be defined in specific units such as grams, candle-power, amperes, etc., or they may all be reduced to the absolute unit or energy, the erg. Thus Langley determined that the just perceptible light sensation under favorable conditions was stimulated by .0000003 erg. The just perceptible sound stimulus is represented by a figure considerably smaller.

Interest in these quantitative aspects of psychology, or in the science of psychophysics as it came to be called, dates from the researches of the German physiologist, Ernest Heinrich Weber (1795-1878), at the University of Leipzig, who in 1849 published his celebrated work "On the Sense of Touch and Organic Feelings." He experimented with lifted weights and found that he could just distinguish weights of 32 and 35 drachms. He found further that in order to make a weight just noticeably different from one of 32 ounces it was necessary to make a certain proportional rather than an absolute difference between the weights compared, i. e. 3 ounces instead of 3 drachms. Weber stated his conclusions as follows: "In the discrimination of objects that are compared the one with another, we do not perceive the difference between the objects but the ratio of this difference to the magnitude of the compared objects."

His work was followed by that of Gustav Theodor Fechner (1801-1887), who had at one time held the chair of physics and later that of philosophy at Leipzig. Fechner gave the name "psychophysics" to the new field of investigation, carried on many experiments in practically all the different sense fields, and wrote extensively on the subject's mathematical and philosophical aspects. He gave the name of Weber's Law to the psychophysical principle as stated by his predecessor.

Fechner sought to give a mathematical statement to the psychophysical law. The functional relationship between the sensory response series and the accompanying stimulus series he expressed by grading the former in an arithmetical progression and the latter in a geometrical progression. The mathematical relation between two such progressions or series may be expressed by saying that successive terms of one are respectively directly proportional to the logarithms of the successive terms of the other. Fechner's mathematical statement of the psychophysical law then becomes—

$$R \propto \log S$$

where R is the response or sensation and S the stimulus. Here we have a formula analogous to that for the magnetic deflection of the tangent galvanometer where

$$A \propto \tan \theta$$

when A equals the current strength and θ equals the total angle of deflection.

Fechner's law, as the logarithmic statement of the psychophysical principle has been called, may then be stated in one of two ways:

(1) *If stimuli are arranged in a geometrical series the sensations (responses) accompanying them will form an arithmetical series; or*

(2) *The sensation (response) is directly proportional to the logarithm of the stimulus.*

For Fechner, of course, the sensation aroused by a just noticeable stimulus was a sensation unit, in terms of which other supraliminal sensations and sensation differences as elements in consciousness could be measured.

An approximately exact illustration of this law is found in the magnitude of the visible stars. The classification of stars according to their brightness goes back to Hipparchus (125 B. C.) and Ptolemy, who divided the naked-eye stars arbitra-

rily into six "magnitudes", the first magnitude stars being some twenty of the very brightest and the sixth magnitude stars those just visible to the unaided eye. Now a first magnitude star is about one hundred times as bright as a sixth magnitude star. Stars may, therefore, be divided arbitrarily on the basis of photometric findings by the use of a light ratio of 2.51 ($\sqrt{100}=2.51$). That is, a star of the second magnitude is 2.51 times as bright as one of the third, one of the third 2.51 times as bright as one of the fourth, and so on. This method, first proposed by Pogson in 1850, has been generally adopted and most of the naked-eye stars have been measured photometrically and placed on this "absolute scale."

It would be gratifying if all stimulus series and response series parallel to them were found to conform to this simple functional relationship. When we test these series in different sensory fields for varying intensities, qualities, durations, etc., we find only a rough approximation of Fechner's law and that is usually limited to rather narrow ranges of these series. Weber's statement of the psychophysical principle is more nearly accurate because more general. We do not perceive or react to the difference between compared stimuli or objects, but the ratio of their difference to their magnitudes. Thus formulated we have a law which seems to be substantiated by the results of experimentation.

The data of extensive experimentation in this field both by the so called *gradation methods* and *error methods* (method of mean error, method of constant stimuli, etc.) are conveniently treated by the mathematics of probability and error in ways similar to the treatment of a series of data obtained from any scientific instrument of precision. The results show the sensitivity or degree of precision in any single observer as well as differences among different observers.

The statement of the principle of relativity as found in Weber's psychophysical law has not been confined to psychology. We find it in the principle of marginal utility in economics. As pointed out by Bernoulli (Daniel Bernoulli, 1700-1782), "we may regard the satisfaction which a person derives from his income as commencing when he has enough to support life, and afterwards as increasing by equal amounts with every equal percentage that is added to his income; and vice versa for loss of income." (A. Marshall, "Principles of Economics," 6th ed. p. 135.). Of course, the term "satisfac-

tion" is a psychological concept and the principle of Bernoulli and that of Weber are probably fundamentally the same. In other words, the "marginal utility" of any commodity to its possessor diminishes with every increase in the amount of this commodity which he already has.

Just as we notice the increase in light when a second electric light is turned on in a room but do not notice an additional light in the room already illuminated by a thousand lights, so ten dollars makes an appreciable increase in the monthly wages of a chauffeur but would not be noticed if added to the income of the millionaire whose car he drives. It is a "drop in the bucket" to use a folk-phrase expressing this principle, while "an inch on the end of a man's nose" is another folk-phrase to express a difference which is readily appreciable.

An example of this principle comparable to the psychophysical law is seen in the relation of rainfall to agricultural production. Before wheat can be grown at all a minimum amount of annual rainfall is necessary. This is the rainfall threshold, and we have a "just possible" wheat production. Even small increases in this rainfall yield rapid increases in the amount of wheat per acre which can be grown. But this rate of increase in production will fall off rapidly, and whereas an increase from 12 to 20 inches may double the crop, the increase from 40 to 48 will not do so. Finally a point is reached where further increase in rainfall will not increase the crop but may even be harmful and lessen production.

Scientific instruments frequently yield data which may show constant as well as variable errors. The constant error of a ship's chronometer is a certain regular rate of gain or loss per day. The instrument is set for Greenwich time and its time readings are compared from day to day with the true time as determined by some observatory. Its regular gain may be three seconds per day. This is a constant error. But continued observations show that it is not exactly three seconds: it is sometimes slightly more or slightly less than this. This difference is the variable error and may be due to one or many unavoidable causes. The navigator makes allowance for the constant error, but the variable error remains and must be taken into account as affecting the certainty of a given time observation. Considered as an instrument of precision the human being acting as an observer may show both constant and variable errors. This constant error when present in

observers is known as the "personal equation." The history of its discovery is interesting.

In the records of the Astronomical Observatory at Greenwich we find the following entry made by the British Astronomer Royal, Nevil Maskelyne, (1732-1811), who writes after holding that position for thirty years:

"I think it necessary to mention that my assistant, Mr. David Kinnebrook, who had observed the transits of stars and planets very well in agreement with me all the year 1794, and for the greater part of the present year, began from the beginning of August last to set them down half a second of time later than he should do according to my observations; and, in January of the succeeding year he increased his error to eight-tenths of a second. As he had unfortunately continued a considerable time in this error before I noticed it, and did not seem likely to get over it and return to a right method of observing, therefore, though with reluctance as he was a diligent and useful assistant to me in other respects, I parted with him.

"The error was discovered from the daily rate of the clock deduced from a star observed on one of two days by him and on the other by myself, coming out different to what it did from another star observed both days by the same person, either him or myself. . . .

"I cannot persuade myself," he continues, "that my late assistant continued in the use of this excellent method (i. e., Bradley's eye and ear method) of observing, but rather suppose he fell into some irregular and confused method of his own, as I do not see how he could have otherwise committed such gross errors."

This record made by Maskelyne is the first account we have of any observation of a personal equation. Maskelyne considered that the discrepancies between his and his assistant's observations were due to some faulty method on his assistant's part and did not concern himself with investigating the matter further. The incident of Mr. Kinnebrook's dismissal was, however, mentioned in a history of the Greenwich observatory published twenty years later (1816) and here it attracted the attention of Bessel (Friedrich Wilhelm Bessel, 1784-1846), the Königsberg astronomer.

It was hard for Bessel to see how an assistant, who would have every reason for bringing his observations into agreement with those of his superior, should have so persistently shown this constant error. To test the matter for himself he compared his own results with those of other astronomers. In December, 1820, he observed ten stars on alternate nights with Dr. Walbeck, determining the rate of the clock as Maskelyne and his assistant had done. When they first compared their results

they found a difference not of 0.8 seconds, but of 1.1 seconds. Being trained astronomers, they took particular precautions on the following two days, but with very little difference in the result, for the discrepancy was nearly one second (average for eight days 1.04 seconds). So careful were they that Bessel wrote, "We ended the observations with the conviction that it would be impossible for either to observe differently, even by only a single tenth of a second." Still Bessel was not satisfied. Walbeck was less experienced in transit observations than he, and so similar comparisons were made either directly or indirectly with many of the best astronomers of Europe.

It became recognized, therefore, that there is in each observer a tendency to observe star transits in a characteristic way which may differ in time results from other observers equally well trained (the relative personal equation), and that these time results differ by a more or less constant amount from the true time measured (the absolute personal equation). What applies in observing star transits by the eye and ear method applies more or less generally in all cases where a person reacts in any way to a certain stimulus. This "constant error" is analogous to the error of the chronometer and in a similar way it may be determined within certain limits of variation and allowed for. We see, therefore, that in many ways the observer is an instrument of precision, having, as do other scientific instruments of precision, a certain degree of sensitivity, a certain interval of uncertainty, and certain constant and variable errors. We may infer also that the analogy of the galvanometer, the chemical balance, etc. is not certainly merely an analogy.

THE ALIMENTARY TRACT OF THE COMMON BUMBLEBEE.

MILLARD C. SWINGLE.

INTRODUCTION.

The insects as a class offer more opposition to man than does any other class of animals. Indeed, the order Hymenoptera is the only group which is truly beneficial to man. It includes the ants, all the bees, both polonizing and honey-making, and all the parasitic wasps which keep in check other insect pests. Since the group is one of man's greatest allies, a knowledge of them is of importance.

For the present study a representative type, the common bumblebee, *Bremus pennsylvanicus* was taken. This is a medium-sized species with a black head, a black band between the wings, and black underparts. The outer border of the tibia is concave. Only male specimens were used in this work.

All the specimens were fixed in Carl's Fixitive and were preserved in 70% alcohol. Following this, both gross dissection and micro dissection were carried out.

1. *Gross dissection.* This was done by completely removing the dorsal wall of the insect, including the head. The tract is held in place by muscles, trachea, and by the tissue composing the air sacs.

2. *Micro Dissection.* The entire alimentary tract, including the oesophagus and rectum, was removed and imbedded in paraffin. The section was pinned out on cardboard during clearing to insure all parts being on the same level. Sections were then cut eight microns in thickness and stained in Delafield's haematoxylin and eosin. Cross sections were also made of the parts desired.

Drawings of the muscular network of the canal were made from unstained mounts, so the nuclei were not drawn.

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GROSS ANATOMY OF THE TRACT.

- | | |
|-----------------------|----------------------|
| I. Mouth-parts. | III. Mid Gut. |
| II. Fore Gut. | 1. Stomach. |
| 1. Pharynx. | IV. Hind Gut. |
| 2. Oesophagus. | 1. Malpighian Tubes. |
| 3. Honey Stomach. | 2. Pyloric Valve. |
| 4. Proventriculus. | 3. Intestine. |
| 5. Oesophageal Valve. | 4. Colon. |
| 6. Salivary Glands. | 5. Rectum. |

THE MOUTH-PARTS.

The appendages of the head comprising the mouth-parts are practically external. The ventral part of the head has no chitinous floor of its own, but is closed by the bundle of mouth-parts fitting tightly against the opening. When extended, the mouth-parts are twice the length of the head, and are more or less heavily constructed.

They are composed of the following parts:

(1) The Hypopharynx, which is a long cylindrical tube covered with yellow spines. These are arranged in rows running spirally around the tube. The mouth is at the apex of the tube, on the ventral surface. (Fig. 2).

(2) The Labium, which is represented by the palpi only, extending out toward the end of the hypopharynx, is composed of three visible segments, the basal large, and the others very small.

(3) The Maxillæ are well represented by the long lacinia which extend to the apex of the labial palpi.

(4) The Mandibles are short and extend only to the base of the hypopharynx.

All of these parts are capable of being folded into a cylindrical-shaped organ, which bends in the center and folds back under the head when not in use.

THE FORE GUT

The fore gut is ectodermal in origin, having been formed by the invagination of the fore part of the embryo. It is about a half inch in length, reaching from the mouth to the fore part of the mid gut. It is thin, membranous, and almost transparent its entire length, except for the proventriculus and oesophageal valve. (Fig. 1).

On leaving the proboscis, the tract bends forward and upward into the fore part of the head. It passes along the

upper part of the head toward the back, where it suddenly bends and proceeds down through the two lobes of the brain, and then straight back through the thorax into the abdomen, where it ends at the junction of the first and second segments. It is cylindrical and relatively small for most of its length until it reaches the abdomen, where it is greatly dilated, forming the honey stomach.

The Pharynx resembles the oesophagus in general appearance, but is more dilated and irregular. It is several times the diameter of the oesophagus, at its anterior end, but narrows at its posterior border where it empties into the oesophagus. It is not clearly differentiated from the oesophagus anywhere along its course, except in size and possibly in having a thicker covering of muscles.

The Oesophagus is a long tube extending from pharynx to the honey stomach. Its diameter is constant throughout the entire length. Like the pharynx, it is practically transparent and has a waxy appearance.

The Honey Stomach is formed by the greatly dilated posterior end of the oesophagus. It is about six or eight times the diameter of the oesophagus. It also has the same structure and appearance as the pharynx and oesophagus. (Fig. 1).

The Histology of the Fore Gut is as follows:

- (1) A cuticula of chitin on the inner surface.
- (2) An epithelial layer of hypodermal cells.
- (3) A basement membrane, secreted by the hypodermal cells.
- (4) A band of longitudinal muscle fibers.
- (5) A band of circular muscle fibers.

The three parts of the fore gut already mentioned are alike in structure, (See Figs. 3, 4 and 5, Plate I). The chitinous cuticle is the most prominent layer, and is about four times as thick as the others combined. It is not solid but is made up of a very thin and greatly convoluted sheet of chitin. Under this chitinous layer is an epithelium of very thin flat cells. These are more or less indistinct and in sections have the appearance of a number of nuclei connected by threads. The basement membrane is not apparent in this portion of the fore gut. The longitudinal muscular layer is also very poorly developed. It is represented by a few widely scattered bundles of tissue. The circular muscles are also poorly developed, being represented by a few scattered strands.

The Proventriculus, (Fig. 1, Plate II), is a fleshy tube-like continuation of the posterior part of the honey stomach. In junction with the oesophageal valve it forms a valve-like door for the fore part of the stomach. Its anterior end is closed by four triangular-shaped lobes of tissue, which lean inward when food is passing through. Their inner surface is covered with chitinous spines, which are long at the apex of the lobes and which become shorter as they extend downward along the wall of the proventriculus. They are directed posteriorly into the gut, and probably serve to prevent the food from being forced back out into the oesophagus. The entire inner surface is covered with chitin, which is in the form of a relatively smooth sheet. The epithelial layer is very well developed, being made up of a single layer of oblong cells packed closely together. The longitudinal muscles are very well defined, forming about one third the total thickness of the wall. They run continuously from one end to the other. Around the whole is an enormously developed layer of circular muscles. The outer membrane is not apparent. This is the only part of the entire gut where circular muscles are even moderately well developed. It evidently acts as a force pump for the entire system.

The Oesophageal Valve defines the posterior limit of the fore gut, which is merely a continuation of the proventriculus into the mid gut. It is conical in shape and tapers toward its posterior end, where a thick tuft of convoluted chitin protrudes from the interior. The chitinous layer is thin and not so well developed at the anterior end, but becomes thicker and heavier at the apex. The epithelial cells are not clearly differentiated from the muscles, but are present nevertheless in a scattered layer. A basement membrane is not apparent but the layer of longitudinal muscles is very well defined. It is heavy at the base but gradually branches off and disappears at the apex. The circular muscles are very poorly differentiated, being represented by a few scattered bundles. Surrounding the whole is a fairly well defined sheathing membrane.

In the oesophagus the chitin layer is the most prominent, while the other layers are relatively unimportant. In the proventriculus, the circular muscles are most prominent with the longitudinal ones next. In the oesophageal valve the longitudinal muscles are by far the most important.

The Salivary Glands belong embryonically to the fore gut. There are three main glands, two of which are cephalic, and the other thoracic, (Fig. 8, Plate I). They are all paired, one gland lying on either side of the median line. The super-cerebral gland lies against the dorsal wall of the head, and is the smallest of the three. A duct leads downward and forward, and enters the pharynx in the fore part of the head. The post-cerebral glands lie back of the brain in the posterior part of the head. The frontal gland is merely the fore part of the post-cerebral gland. A duct leads from them inward and enters a main duct in the center of the head, which empties into the hypopharynx. The thoracic glands are large, and lie about the oesophagus, extending about half way back through the thorax. A duct leads from them forward and empties into the duct from the post-cerebral glands. All of the glands are well developed and occupy a large part of their respective body cavities.

The fore gut appears to be a conductor only. Other than the salivary glands, there appear to be no cells for secretion in this gut. Food is merely carried from the mouth to the stomach by this gut, and with the exception of the salivary fluid, is not affected by it.

THE MID GUT.

The stomach comprises about one-fourth of the entire length of the alimentary canal. (Fig. 1, Plate I and Figs. 1 to 5, Plate II). In diameter it is about four times the size of either the fore or hind guts. It is entodermal in origin, being formed by a proliferation of rings of tissue from the free ends of the embryonic stomodeum and proctodeum. Its most conspicuous layer is that of the digestive epithelium. The cells are arranged in circular folds, there being approximately one hundred and forty folds from the oesophageal valve to the pyloric valve. The epithelium is somewhat columnar, but not strikingly so. The cells are rounded and present a diagrammatic regularity as they fold up and down, forming in longitudinal sections papillæ-like projections into the gut. This type of gut has been formed from a gut having a straight, flat epithelium. Pressure applied to the ends would force the epithelium to lap back and forth accordian-like, into folds extending circularly about the stomach.

Outside this layer of cells is a fairly well defined basement membrane, which is in contact with each cell in the fold. It therefore undulates in keeping with the epithelial layer.

Between the folds and at their base are scattered bundles of muscle fibres. These are circular muscles, and have been squeezed down between the walls of cells by the folding action of the gut.

On the outside is a thin layer of longitudinal muscles composed of bundles of longitudinal muscles connected by strands of lateral fibres, the whole forming a lattice-like network. Due to the scarcity of these strands, the external wall of the stomach appears corrugated. This layer may not be functional as a muscular layer, but rather as a covering. There is no apparent sheath-like layer beyond this. (Fig. 7, Plate I).

The area about the oesophageal valve is smaller in diameter than the rest of the gut, probably because of the fact that food rarely finds its way into this cavity, being emptied farther out into the gut at the end of the valve. The cells in this region are small and are of a dense type of protoplasm. The nuclei evidently are of a weaker structure, since they appear coarsely granular when stained. The cells appear to be non-functional as far as secretion is concerned. (Figs. 2 and 4, Plate II).

The portion of the stomach behind the opening of the valve presents an entirely different view. In this portion all of the cells, and especially those at the ends of the folds, are quite large. The nuclei are apparently very dense, for they stain evenly and very darkly. It is not an uncommon thing to find cells here which are six or eight times the size of those about the oesophageal valve. Evidently this is the source of secretion in the gut. The secretion is holocrine in this type of gut. The cell forms the digestive enzyme within itself until a certain quantity is collected and then the cell bursts open, liberating the enzyme into the gut. The old tissue is detached and the newer cells behind it move forward and take its place. At the base of the fold is a group of small cells called a nidus. From this nucleus of cells new cells are formed which move out and take the place of the cells which have completed secretion. In this way there is a constant change of cells as secretion progresses. (Figs. 2 and 5, Plate II).

At the anterior end of the mid gut is a circular ring of cells which surround the base of the oesophageal valve and which secrete a thin membrane extending back into the gut. This is called the peritrophic membrane, and extends the entire length of the mid gut. At the apex of the valve there are several elongate folds of the stomach wall, which extend into the gut

almost to the valve. At this point the peritrophic membrane becomes thickened, but whether these folds have anything to do with secretion is not clear. The membrane is secreted only at the anterior end of the gut and is carried along to the other end by continued secretion.

THE HIND GUT.

The hind gut comprises about one-half the length of the alimentary tract. It is small in diameter and rather muscular for most of its course, but becomes translucent and thin at the colon and rectum. There are five main parts to the hind gut. (Fig. 1, Plate I, Figs. 1 to 5, Plate III).

The Malpighian Tubes. At the junction of the mid gut with the hind gut, is a series of small tubes branching off in all directions, called the Malpighian tubes. There are approximately one hundred and twenty-five to one hundred and fifty tubes in all. They are arranged in three parallel, circular rows about the gut, and are rather small in diameter. They weave in and out among the folds of the gut and serve to hold it in a compact mass in the center of the abdomen. They are probably urinary in function, emptying their contents into the hind gut. (Figs. 1, 4 and 5, Plate III).

Within each tube is a small canal. Next is a layer of cells forming an epithelium, which is relatively thick and forms the true body of the tube. The cells are somewhat flat, being about twice as broad as deep. Surrounding the whole is a thin membrane of connective tissue.

The Pyloric Valve is a ring of elongated cells extending down into the hind gut at its anterior end, just posterior to the Malpighian tubes. The epithelial layer of the gut has merely bulged out into the cavity, and the cells have become elongate.

The Histology of the Hind Gut is as follows:

- (1) A cuticula of chitin on the inner surface.
- (2) An epithelial layer of hypodermal cells.
- (3) A basement membrane.
- (4) A layer of circular muscles.
- (5) A thin layer of longitudinal muscles.
- (6) A layer of circular muscles.

The gut as a whole is ectodermal in origin, being formed by an invagination at the posterior end of the embryo.

The Five Parts of The Gut are as follows:

The Malpighian Tubes. These are tubes formed by the epithelium and basement membrane. They do not possess the other layers.

The Pyloric Valve. The general characteristics of this valve have been described above. Its histology is identical with that of the intestine, except that the epithelial cells are two or three times as long as those in the intestine.

The Intestine. The chitinous layer is thin and relatively smooth. It lies compactly against the tips of the cells and is not folded in any way. The epithelium is of the columnal type, with nuclei at the basal ends of the cells. The cells are rounded at each end and are about three times as long as broad. There is no very definite basement membrane. The three layers of muscles are not easily differentiated. The circular muscles are well developed, but the longitudinal muscles appear only as short strands connecting each circular bundle with the next. The inner and outer layers of circular muscles are well defined. They fit so closely together that they appear as one layer. This is due to the fact that the strands of the outer layer have fallen down between those of the inner. The two layers form a lattice-like network, with the main strands running circularly about the gut. At intervals between these circular bundles, there will appear a longitudinal bundle of muscles. There is no apparent membrane around the whole. (Fig. 6, Plate I).

There are five longitudinal folds of the epithelium extending into the intestinal cavity. These extend from the Pyloric valve to the rectum. They are produced by convolutions of the epithelial layer. (Fig. 2, Plate III).

The Colon. This is a large sac-like structure at the posterior end of the intestine, and into which it empties. It is thin, translucent, and waxy in appearance. In diameter it is four or five times the size of the intestine. The chitinous lining is greatly wrinkled and convoluted, while the epithelium and muscle layers are thin and serve only as a covering. It is similar in structure to the oesophagus and honey stomach. The muscular layers are very thin and indistinct, but the longitudinal layer seems to be the most prominent. The natural position of the colon is against the dorsal surface of the body wall.

The Rectum. The colon leads back posteriorly under a dorsal anal sclerite, where it becomes very narrow and enters the rectum. The rectum broadens out and has its entire dorsal surface attached to the sclerite above it. It is held in place also by a thin chitinous plate which entirely covers it below and is attached on either side to the sclerite above. The anal opening is merely an opening in the articular membrane at the end of this dorsal sclerite, beyond the rectum. The rectum itself is not constricted at its opening but opens with its entire diameter.

The rectum is more chitinous than any other part of the gut. Its epithelial layer and muscles form only a thin covering. No rectal glands were found. Perhaps they do not occur in the male bee, though they are so very conspicuous in other Hymenoptera.

SUMMARY.

The alimentary tract as a whole is about twice as long as the body of the insect. The oesophagus is straight and leads back to the stomach in a direct line. The stomach and intestine are coiled upon themselves and are bound together by the mass of malpighian tubes. The fore gut is thin and practically transparent, except for the proventriculus and oesophageal valve. The mid gut is thick and corrugated, and is composed mostly of epithelial tissue. The hind gut is small and opaque except for the colon and rectum, which are somewhat transparent.

The entire system is rather simple and unspecialized. In each part of the canal there is but one prominent layer, which seems to have been evolved toward carrying on the entire function of that specific part of the gut. The other layers are often more or less discontinuous and vestigial.

BIBLIOGRAPHY.

1. BORDAS, L.
Appareil Glandulaire des Hymenopteres. 1894.
2. BORDAS, L.
Les Tubes de Malpighi des Hymenopteres. (Bulletin Scientifique, 1895).
3. BUGNION, E.
L'estomac du Xylocope violet (X. violacea Fabr.).
4. CHAMBERS, V. T.
The Tongue of some Hymenoptera.
5. NELSON, J. A.
Morphology of the Honey Bee Larva.
6. SEMICHON, M. L.
Sur l'Epithelium de l'Intestin moyen de quelque Melliferes, (Bulletin du Museum d'Histoire Naturelle, 1903).

EXPLANATION OF PLATES.

PLATE I.

- Fig. 1. A dorsal view of the alimentary tract. Oe.—Oesophagus; H. S.—Honey stomach; S.—Stomach; Int.—Intestine; Rec.—Colon and rectum.
- Fig. 2. The mouth-parts (Mandibles not shown). Hyp.—Hypopharynx; La.—Lacinia; La. P.—Labial Palp.
- Fig. 3. Cross section of the oesophagus.
- Fig. 4. Cross section of the honey stomach. C.—Chitin.
- Fig. 5. Section of wall of sesophagus. C.—Chitin; Ep.—Epithelial cells; C. M.—Circular muscles.
- Fig. 6. Muscular network around Intestine. C. M.—Circular muscle; Int.—Intestine.
- Fig. 7. Muscular network of stomach. L. M.—Longitudinal muscle.
- Fig. 8. The salivary glands. Hyp.—Hypopharynx; S. D.—Salivary duct; Ph.—Pharynx; F. Gl.—Frontal or post-cerebral glands; Pc. Gl.—Post-cerebral Glands; T. G.—Thoracic Glands; Sc. Gl.—Super-cerebral glands; Oe.—Oesophagus.

PLATE II.

- Fig. 1. Longitudinal section of the proventriculus. L. M.—Longitudinal muscles; Sp.—Spine; Pvts.—Inner canal of proventriculus; Hy. Ep.—Hypodermal epithelium; C.—Chitin; Ho. St.—Honey stomach; M. G.—Mid gut; Es. V.—Oesophageal valve.
- Fig. 2. Longitudinal section of oesophageal valve. Pvts.—Proventriculus; Oe. V.—Oesophageal valve; St.—Stomach.
- Fig. 3. Diagrammatic sketch of one-half of stomach, showing arrangement of the inner folds.
- Fig. 4. A section of two of the folds in the fore part of the stomach lying about the oesophageal valve. C. M.—Circular muscle; C. Mar.—Ciliated margin of cells.
- Fig. 5. A section of two of the folds of the stomach beyond the oesophageal valve. N.—Nidus; C. M.—Circular muscles; C. Mar.—Ciliated margin of cells.

PLATE III.

- Fig. 1. Longitudinal section of pyloric valve. Int.—Intestine; Ep.—Epithelium; C.—Chitin; C. M.—Circular muscles; V.—Valve proper; M. T.—Malpighian tubes; St.—Stomach.
- Fig. 2. Cross section of intestine. Ep.—Epithelium; L. M.—Longitudinal muscles; C. M.—Circular muscle.
- Fig. 3. Longitudinal section of junction of intestine and colon. Int.—Intestine; Ep.—Epithelium; Rec.—Colon or rectum.
- Fig. 4. Cross section of Malpighian tube.
- Fig. 5. Longitudinal section of Malpighian tube.

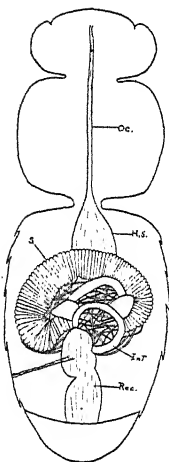


Fig. 1

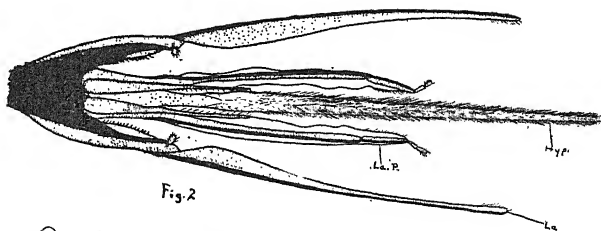


Fig. 2

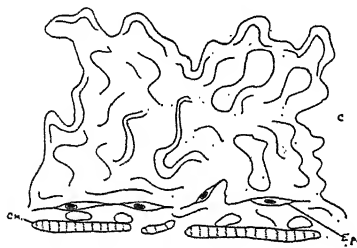


Fig. 3



Fig. 4



Fig. 5

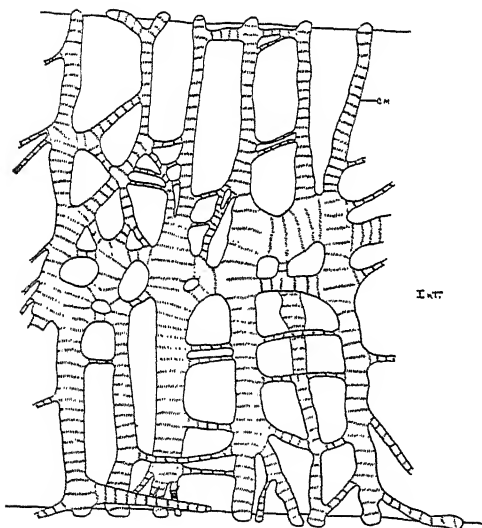


Fig. 6

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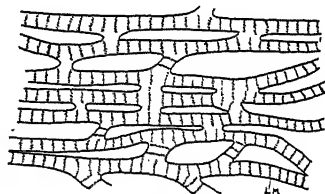
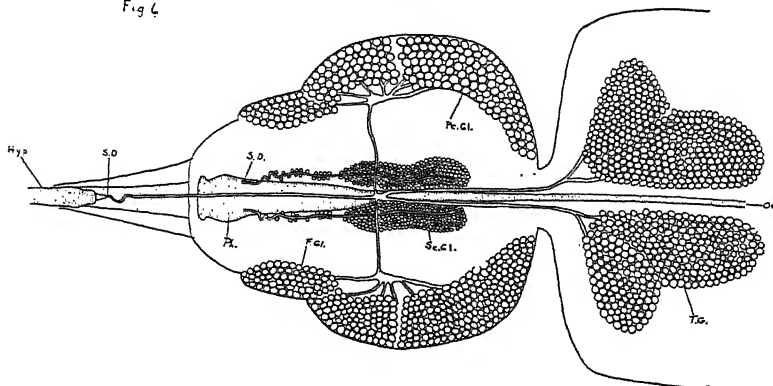
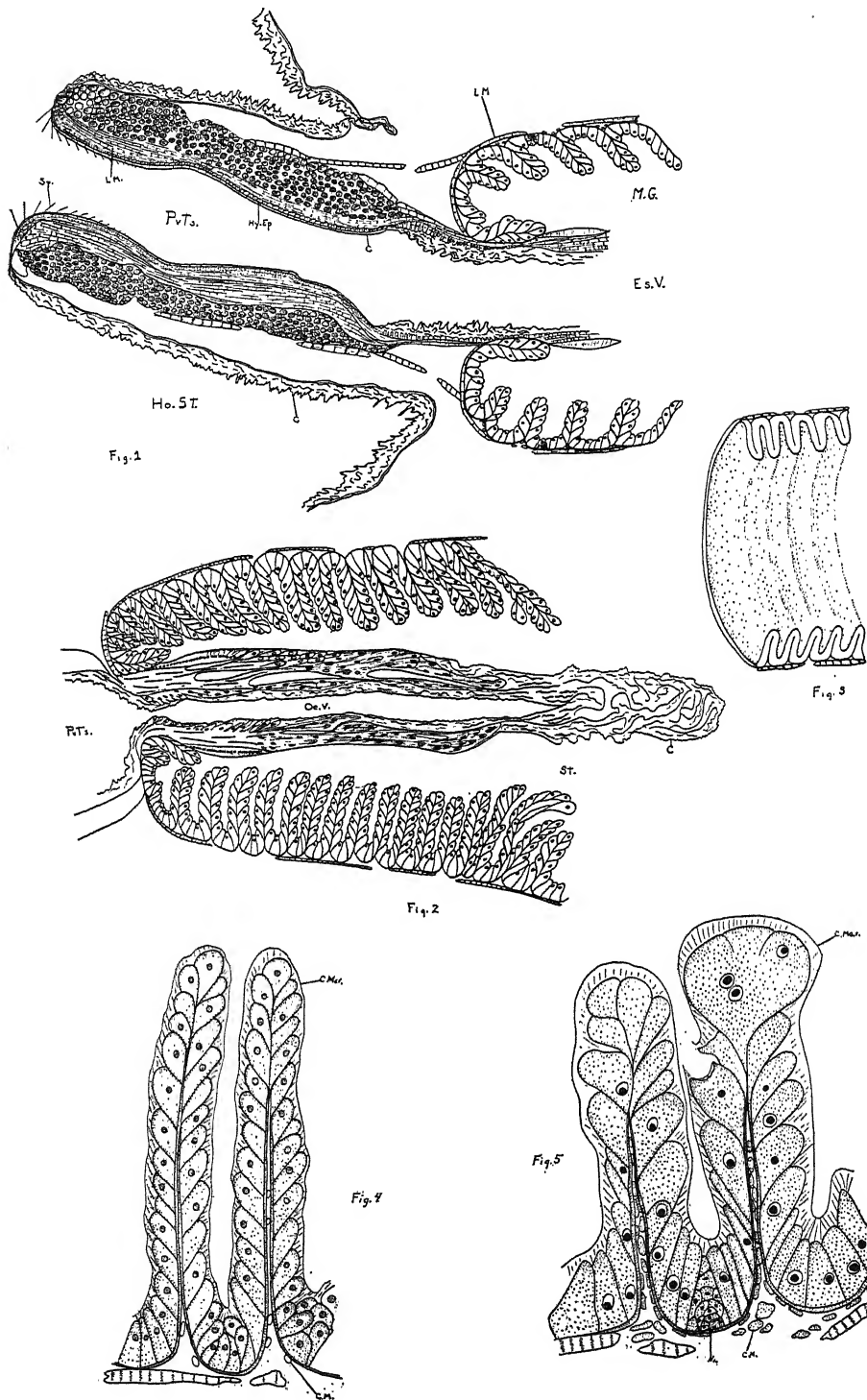


Fig. 7





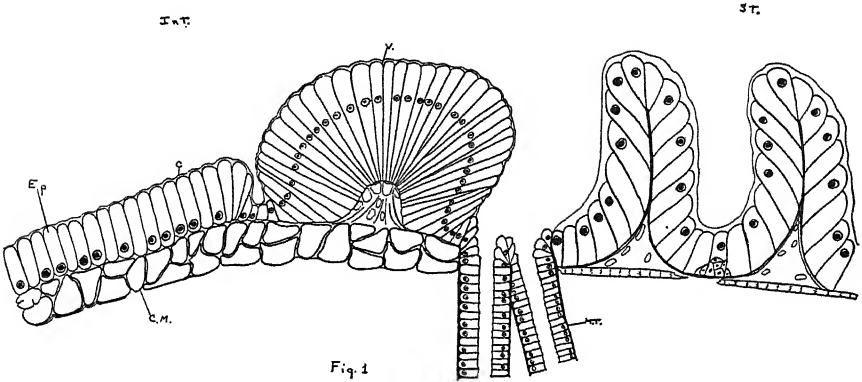


Fig. 1

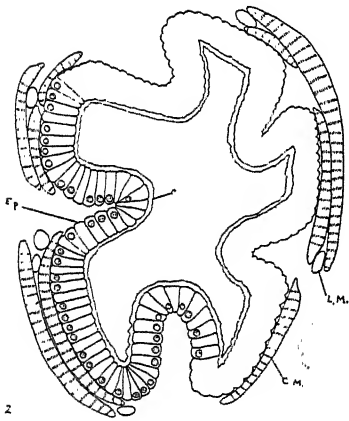


Fig. 2

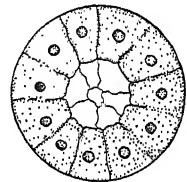


Fig. 3

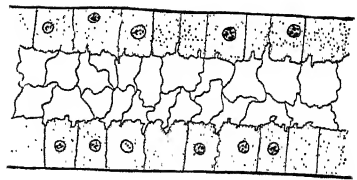


Fig. 4

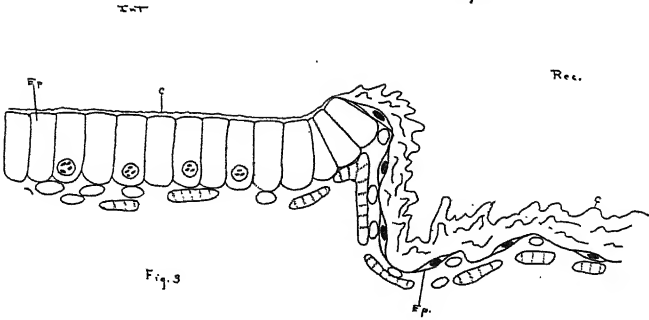


Fig. 5

FUSARIUM MONILIFORME IN RELATION TO DISEASES OF CORN.

D. P. LIMBER.

INTRODUCTION.

The fungus, *Fusarium moniliforme* Shel. has been reported by several workers (15) (20) to be the cause of ear, stalk, and root rots of corn. The rotting of the corn plant causes very serious losses to the crop. Other organisms parasitic on corn are known to cause the rotting of ears, stalks, and roots of corn, notably, *Diplodia zeae* (Schw.) Lev. (2) *Gibberella saubinetii* (Mont.) Sacc. (7), *Helminthosporium* sp. (18), and certain bacteria (14). Hoffer and Carr (6) have shown that effects very similar to stalk and root rots are produced by excessive accumulation of iron and aluminum in the roots and stalks of corn.

The consideration of *F. moniliforme*, specifically, as one of the major causes of stalk rot and seedling blight began with Valteau's work (20) in 1920. Since that time some workers have advanced evidence supporting Valteau's findings, others have secured contrary results.

The work reported in this paper was undertaken to ascertain if *F. moniliforme* is capable of causing a serious seedling blight of corn; if *F. moniliforme* causes broken and leaning stalks in the field; to what extent it causes molding of ears; and in what way infection reaches the kernels. Incidentally, the problem of seed treatment was taken up in order to secure disease-free seed for inoculation purposes.

A review of literature follows which shows the present status of these problems.

REVIEW OF LITERATURE.

The fungus known as *F. moniliforme* Shel. was described by Sheldon (15) in Nebraska in 1904. He isolated it from ears of corn showing a pink mold, and described it as follows:

"Sporodochium, subeffuse, salmon-pink; sporophores, simple or branched, usually opposite; microconidia, continuous, oblong-

ovoid, moniliform, 6–10 μ long; macroconidia, falcate, acute, for the most part three-septate, 25–40 μ long”.

Sherbakoff (16) states that “among the *Fusaria* answering Sheldon’s description of *Moniliforme* are several that differ from each other in important characters and are thus different organisms.” On these grounds he set up the section *Moniliform* as follows: “Macroconidia type intermediate between *Roseum* and *Elegans*, thin walls mostly three-septate; microconidia also in chains, chlamydospores none, color of substratum from none to violet.”

Manns and Adams (11) identified *F. moniliforme* with *Oospora verticilloides* Sacc. reported from Northern Italy in 1881.

Wineland (21) at Wisconsin reported that perfect perithecia were produced when two distinct strains of *F. moniliforme* were plated together. The perithecia were born at the lines where the two strains came in contact. Ascospores from these perithecia on germination gave pure cultures of *F. moniliforme*. The cultures which produced the perithecia were somewhat different morphologically. The perithecia resembled those of *G. saubinetii*.

Stover (18) at Wisconsin studied the effect of temperature on the growth of *F. moniliforme* in culture. After five days visible growth had occurred at a temperature of 12° C., was considerably greater on plates up to 18° C., then increased more gradually to an optimum from 26° C. to 33° C., after which it decreased markedly at each higher temperature. There was little growth at 37° C. Henry (5) gave its temperature range as follows: “slightly at 5°–7° C., optimum at 30° C., and slightly at 36°–36.5° C. He also reports isolating *F. moniliforme* from the soil.

It is probable that many investigators have worked with *Fusarium moniliforme* in connection with studies of seedling blight of corn. There are many papers on this subject which do not name all the organisms studied. Burrill and Barrett (2), Holbert and Hoffer (8), and Pammel, King, and Seal (13) mention a *Fusarium* in this connection.

Valleau (20) in 1920 was the first to assign to *F. moniliforme* any large part in the production of root and stalk rots. He found that it was almost universally present in Kentucky seed corn. He also secured corn from other states and found infection equally high. On the basis of his work he believed

that *F. moniliforme* was an active parasite, more virulent than *G. saubinetii*, that it was capable of causing root and stalk rots in the field, but that it did not injure germination unless infection were very severe. Manns and Adams (10) in Delaware report that *F. moniliforme* is very common in seed corn. Branstetter (1) in Missouri found *F. moniliforme* was present in 68.8% of the ears he tested. He also reported a correlation between badly diseased corn, as shown by the germinator test, and low yields. Melchers and Johnson (12) in Kansas found nearly 95% of the seed corn was infected, but could find no correlation between the results of the germination test and stalk and root rot injury in the field.

Sherbakoff (17) reports that seed effectively treated for *F. moniliforme* gave no better yield than untreated seed. He suggests that either it is not pathogenic or that it is always present in the soil. Valteau (20) reported that he could find no effective treatment. Manns and Adams (11) state that the internal nature of the infection makes seed treatment ineffectual. Branstetter (1) states that seed corn can be effectively treated by soaking it in mercuric chloride (Hg Cl_2) 1:1000 for one hour.

The effect of soil temperature on the blighting of corn seedlings inoculated with *F. moniliforme* was investigated by Stover (18). He found that *F. moniliforme* attacked corn through a range of soil temperature from 10° to 36° C. However, at the lower temperatures, infection was rare and was shown only by small brownish-yellow lesions which did not represent a serious injury. At 28° to 36° C. seedlings showed considerable injury and *F. moniliforme* was frequently isolated from the lesions. It was thought that high temperature with consequent drying of the surface soil was at least in part responsible.

F. moniliforme has been reported from hosts other than corn. Hartley, Merrill, and Rhoads (4) as early as 1918 found that *F. moniliforme* caused normal damping off of conifer seedlings, but was not responsible for germination injuries except when heavy inoculation was practiced. They concluded that it was less important in damping off of conifer seedlings than *Corticium* and *Pythium*. Henry (5) inoculated *F. moniliforme* into wheat, sweet corn, rye, and oats, all of which it attacked.

EXPERIMENTAL WORK

The writer's work with *F. moniliforme* Shel. was undertaken during the summer of 1923 at Ohio State University. A small plot of corn in the Botany Department garden was used for field inoculations. The seedling inoculations and soil temperature experiments were carried on in the department greenhouse and laboratory.

Many strains of *F. moniliforme* were used during the progress of this work. Three strains were secured from Mr. R. A. Dobbins, a graduate student in the Department of Botany. Two were isolated from blighted corn seedlings sent in from Morrow County in June 1923. The others were isolated from kernels of corn. In all thirteen strains were secured. Single spore isolations were made from five of these. All of the strains produced macroconidia in chains. The microconidia were produced abundantly in old cultures which had been kept moist. Three and four septate macroconidia were the most common. Five septate macroconidia were frequent. These latter often measured 50–60 μ in length.

From a study of the morphology and physiological reactions of these strains in culture it became apparent that they could be separated into at least two distinct groups. The mycelium of the group most closely answering Sheldon's description had a pink tint, was loosely matted, and grew freely into the air. The substratum was deeply colored, ranging from greenish blue or purple on potato dextrose agar with 2% sugar to a deep plum purple on potato dextrose agar with 5% sugar. The mycelium of the other group was pure white and formed a low, dense mat. The substratum was never more deeply colored than salmon. These differences are in agreement with Sherbakoff's statement that the fusaria producing spores in chains include several distinct organisms.

FIELD INOCULATIONS.

During the first week in August twenty-five stalks were inoculated just before the tasseling stage to ascertain whether *F. moniliforme* causes stalk rots. A small hole was made in the stalk by puncturing it with a cork borer one-eighth inch in diameter. A fragment of the medium upon which *F. moniliforme* was growing was inserted into the puncture, and the opening was closed with absorbent cotton. The cork borer

and needles used were sterilized in the flame of an alcohol lamp before each operation. Control stalks were prepared in the same way except that no inoculum was placed in the punctures. Inoculations were made at various heights from the ground. The media used were potato dextrose agar and steamed rice.

Two inoculated stalks and two checks were cut and examined after three weeks. Others were cut from time to time until the third week in October. In some stalks it was found that the cork borer had penetrated only the sheaths, the stem not having developed far enough to be encountered. The elongation of the internodes had then pushed the sheaths upward and separated them. The mature plant showed the puncture made by the cork borer in several successive sheaths. These punctures were surrounded by a purplish-black ring of discolored tissue. This is shown in Plate I, a. The check plants did not show this discoloration. In other stalks the cork borer penetrated the internodes. Externally the symptoms were the same as found on the sheaths. When the stalks were split through the wound longitudinally, wide streaks of the pith and vascular bundles were found to be black or brown. These streaks were usually very conspicuous within the internode punctured. This is shown in Plate I, b. In the internodes above and below it they appeared less prominently until in the third or fourth nodes it was confined to the vascular bundles. In one stalk these discolored strands were traced to the sixth node above and to the third node below the inoculation point.

Tissue from the brown strands was taken from six stalks and plated on potato dextrose and corn meal agar. *F. moniliforme* grew out from the tissue in all instances, in one case from tissue taken from a point twenty inches above the puncture. In no case did this discoloration extend into the shank of an ear.

The controls showed a light browning around the wound never extending more than two inches from the injury. No *F. moniliforme* appeared when browned tissue from this source was plated. Several plates showed no fungus growth of any kind. The color of the tissue was probably caused by the death of the cells due to the injury and consequent drying.

Inoculations of leaf sheaths and of stalks made by puncturing these parts with a sterile needle and applying a loop of a spore suspension produced only the local symptoms noted above, purplish-black discolorations confined to the area inoculated.

Five stalks were inoculated by pouring several c.c. of a spore suspension between the sheath and the stalk. No infection could be found when these were examined.

Inoculation on Young Silks.

Valleau (20) suggests that in the ear rot produced by *F. moniliforme* the silks are the path of invasion. To secure data on this point eighty ears were covered with glassine paper bags before the silks appeared. Natural infection of the silks was thus presumably prevented. When the silks were well exposed within the bags, the bags were removed, the silk was pollinated by hand and then sprayed with a suspension of spores of *F. moniliforme*. The bags were then replaced. A large number of control ears were prepared. A severe storm of wind and rain tore or blew off almost all the bags. The purpose of the experiment was defeated by the exposure of the control ears to infection. However, the ears were again covered with a stronger type of bag.

About forty ears each of the inoculated lot and the controls were tested by the modified rag doll method after harvesting. All showed infection. External molding occurred on three or four ear tips to which the corn ear worm had gained access. No other molding was found. This is interesting in view of the heavy inoculation practiced.

Direct Inoculation of Kernels.

The husks of eleven ears were slit with a knife and spores of *F. moniliforme* were sprayed on the kernels. This was done when the kernels were just past the dough stage. In four cases the kernels were wounded, in two they were un-injured by the knife, and in the other cases no attention was paid to this point. Checks sprayed with sterile water were made. In both checks and inoculated ears the slits in the husks were made tangent to the ear in such a manner that the husks would cover the sprayed kernels completely. In ten ears a mold developed, but it was usually confined to from three to six kernels, sometimes scattered. One ear was completely involved. On October fourth nineteen more ears and several checks were prepared in the same way. The corn was nearly ripe and fairly dry. Of these ears only one developed mold.

Inoculation in Cobs of Young Ears.

Seventeen ears were inoculated by puncturing with a cork borer through the husks into the cob of the green ear, then inserting into the cavity a sweet clover stalk or apple twig on which the fungus was growing. These ears were affected much like the preceding. Localized areas where the cavity was near the surface of the cob would show moldy, shrunk kernels. The checks showed no mold. The appearance of this infection is shown in Plate I, c.

Discussion of Results of Field Inoculations.

The results of inoculating the young stalk just before tasseling show that *F. moniliforme* is able to grow parasitically in the stalk tissues and to produce the discolorations characteristic of stalk rot. The absence of broken and leaning stalks seems to indicate that the injury is of a mild character. The slight infection secured in the needle puncture inoculations and the failure of the spore suspension to produce infection when poured under the sheath strengthen this view. As it is possible that other environmental conditions might have changed the results, it would be desirable to repeat these experiments and to make the stalk inoculations earlier in the life of the plant.

F. moniliforme is capable of causing molding of ears but probably requires very moist conditions to cause general molding. It does not attack the husks as freely as *Diplodia zeae* (Schw.) Lev. and *Gibberella saubinetii* (Mont.) Sacc.

SEEDLING INOCULATION.

Inoculation of Seeds at Planting.

Thirty ears were tested for internal infection of *F. moniliforme* by plating pieces of surface sterilized kernels in agar. By this method *F. moniliforme* infected ears and ears apparently free from any fungus were selected. Seed of both kinds was surface sterilized in mercuric chloride (Hg Cl_2) 1:1000 and planted in clean, white sand. Twenty-two apparently disease-free, twenty-three diseased, and twenty-four apparently disease-free inoculated seeds were planted. Each seed was placed in a separate pot and the pots were set closely together in a shallow box. The interspaces were filled with sand to help hold the

moisture. The pots used were made of paper of the type used in making rag doll germinator rolls. Planting each seed in a separate pot prevented the fungi from passing from plant to plant and made it easy to secure the entire root system for examination. The plants were watered with a dilute nutrient solution. They remained thrifty and of good color throughout the experiment.

All of the plants were allowed to grow for four weeks. The soil temperatures ranged between 15.5° and 22° C. At the end of that time the infected and inoculated lots were slightly larger than the apparently disease-free. The difference was thought to be due to temperature as the latter showed a soil temperature 1° to 2° C. lower because of its location farther from the steam pipes. There were nine weak plants from the

TABLE I. COMPARISON OF APPARENTLY DISEASE-FREE, INOCULATED, AND NATURALLY INFECTED SEED GROWN IN SAND FOR ROOT ROT INJURY.

Seed	No. Plants	No. Plants Infected	No. Plants Clean	Percent Clean
Apparently disease-free.....	22	14	8	36
Inoculated.....	24	19	5	24.6
Infected*.....	23	21	2	8.6

diseased seed, four from the inoculated seed, and three from the apparently disease-free seed. The percentage of plants found to have clean roots was 8.6%, 24.6%, and 36% for the infected, inoculated, and apparently disease-free, respectively. Few of the injuries were of an extensive nature. Tissue from the rotted roots and mesocotyls gave *F. moniliforme*, *Gibberella saubinetii*, and other fungi. As the seed used in apparently disease-free and inoculated lots was from the same ears, some infection due to the inoculation is indicated.

This experiment was repeated until in all over four hundred seedlings had been grown. In some of the later lots individual potting was omitted.

This work demonstrated that with the seed used freedom from infection occurred only in individual kernels. No ears were found which were entirely free from *F. moniliforme*. The

*It should be noted that one of the infected ears was of a poor type and not suitable for seed.

percentage of infection was found to vary. Inoculation of ears showing a low percentage of infection increased the amount of infection shown by seedlings grown from such seed. The infections secured under the conditions obtaining in this experiment did not affect the vigor of the plants or cause blighting. It would appear that under these conditions the progress of the infection does not keep pace with the growth of the root system.

Seed Treatment.

The experiments discussed above brought out forcibly the need for disease-free seed or some method of seed disinfection. As no ears had been found to be completely free of fungus infection, several experiments were undertaken in an attempt to find efficient method of seed disinfection.

Hot water treatments proved ineffective. Serious injury occurred at temperatures of 60° C. when maintained for over ten minutes. Seed treated below the point of injury was not disinfected.

Javel water, as used by Duggar and Davis (3) was also tried but did not give complete disinfection.

Mercuric chloride (Hg Cl_2) 1:1000 was also tested. It was found that seed killing began between two and one half and three hours. Some disinfection was obtained when seeds were soaked for one hour and forty-five minutes, but the results were not uniform. Disinfection was then attempted by soaking the seed for ten to fifteen minutes in mercuric chloride at a temperature of 50°–60° C. Several small lots of seed treated by this method and tested were found to be free of *F. moniliforme*. Other lots were then treated by the same method with contradictory results. Incomplete disinfection occurred in some cases; total failure resulted in other cases in which heavily infected seed, as determined by agar plating, was used. These results are perhaps explained when it is remembered that the amount of infection in the different kernels varies widely as is shown by plating and other tests. When infection is light and presumably carried in the more accessible parts of the pericarp, a high percentage of disease-free seeds can be secured by this method.

SOIL TEMPERATURE EFFECTS ON PATHOGENICITY OF *F. MONILIFORME*.

The effects of soil temperature on the parasitism of *F. moniliforme* on corn seedlings were studied by the use of temperature tanks of the Wisconsin type. These tanks are described by Jones (9). These tanks are filled with water, and heated with electric space heaters placed in copper tubes which extend through the tanks near the bottom. The higher temperatures are regulated by electric thermostats. Temperatures below 20° C. are secured by running cold water through the tanks.

The cans were made equal in weight by the addition of pieces of crockery and then filled with equal weights of good soil. The moisture content of the soil was ascertained and corrected to about 24% of the dry weight of the soil. This percentage was maintained by weighing the cans once or twice daily and adding water as was necessary.

The experiment was divided into three parts. One hundred and twenty seeds known to be heavily infected with *F. moniliforme* were inoculated by placing them in a heavy spore suspension, and planted. One hundred and twenty seeds from ears known to be lightly infected were treated by heating in mercuric chloride to 55° C. for ten minutes, followed by thorough rinsing. One half of these disinfected seeds were then inoculated in the way just described, the remainder were planted as a control. By the use of disinfected seed for the control the amount of infection from fungi in the soil would be shown.

The temperatures used were 12°, 16°, 20°, 24°, 26°, 28°, and 32° C. At 32° C. the corn came up in about 2 days and 18 hours, at 28° in 3 days, at 24° in 4 days, at 20° in 5 days, at 16° in 7 days, and at 12° in 15 to 17 days. The disinfected seed germinated 100%, but came up a little more slowly. After the tenth day a tendency to tip burn, and a weakness of the stalks appeared in the inoculated cans at 32° and 28° C. As the experiment progressed, many plants at these temperatures fell over. The check plants were notably stronger and nearly normal in appearance to the end of the experiment. The results of this experiment which was closed after three weeks are presented in Table II.

At 32°C. the control plants were strong and erect, although one plant showed some wilting of the top. The roots or mesocotyls of five plants showed serious rotting; five showed slight

rotting, chiefly of the seminal roots. The old kernel still adhered to the mesocotyls. The disinfected, inoculated plants, of which there were ten, were down badly. The kernels had rotted free of the mesocotyls. Six plants showed serious rotting, while four were only slightly rotted. The twenty infected, inoculated plants were also down quite generally. Two plants were nearly dead and four others were stunted. Fourteen plants had badly rotted roots.

At 28°C. the condition of the plants was much the same as at 32°C. At 24°, 20°, and 16°C. the plants stood up well and appeared to be quite vigorous. The rotting of the roots was not of a serious character except in a few plants. At 12°C.

TABLE II. PERCENTAGES OF PLANTS SHOWING INFECTION WITH *F. MONILIFORME* AT DIFFERENT SOIL TEMPERATURES.

	No. Kernels	Percentage of Plants With Rots or Lesions on Roots or Mesocotyls					
		32°C.	28°C.	24°C.	20°C.	16°C.	12°C.
Control.....	20	80	45	40	10	0	30
Treated seed, inoculated.....	20	85	90	41.5	25	5	10
Naturally infected seed, inoculated.....	40	87.5	92.5	90	50	10	22.5

infection was confined to small lesions, but a serious killing of the tap-root tips occurred which was more common in the cans in which treated seed was used. The plants in the can which showed the most serious killing of the tap roots were from seed from which *F. moniliforme* could not be isolated when plated. These facts suggest that the killing referred to was chiefly a temperature effect, accentuated by some residual effect of the seed treatment.

This experiment was repeated. In the second series the same type of seed was used in all of the cans. It was seed known to be heavily infected with *F. moniliforme*. Two cans of soil for the 32° C. tank were autoclaved for one hour and thirty minutes at 15 pounds pressure. The treated control seed was planted in one of these and the treated-inoculated seed in the other. In this sterile soil 50% of the plants were killed within two weeks. *F. moniliforme* grew visibly on the plants at the surface of the soil. Of the plants in the unsterile

soil at the same temperature all were alive, although two plants showed some wilting. The seed treatment (hot mercuric chloride) was much less effective with this seed and the infection in the control lot was greater than in the first series. Otherwise the results of the two series checked quite closely. The combined results are given in Tables II and III.

Table II is based on a count of all rotted areas and lesions found on the mesocotyls and the seminal and tap roots. The percentages given do not indicate the seriousness of the injury, but the percentage of plants infected.

Table III is based on a count of the plants which showed rotting areas on the mesocotyls or roots, of an actively pro-

TABLE III. PERCENTAGE OF PLANTS SHOWING ACTIVELY PROGRESSING ROTTING AREAS CAUSED BY *F. MONILIFORME* AT DIFFERENT SOIL TEMPERATURES.

	No. Kernels	Percentage of Plants Showing Actively Progressing Areas on Roots or Mesocotyle					
		32°C.	28°C.	24°C.	20°C.	16°C.	12°C.
Control.....	20	45	15	0	0	0	0
Treated seed, inoculated.....	20	60	35	5	5	0	0
Naturally infected seed, inoculated.....	40	70	65	30	2.5	0	0

gressing nature. Lesions and very small infected areas were not considered.

These tables show that the rotting caused by *F. moniliforme* occurs chiefly at temperatures above 20°C. Serious injury was confined to the two higher temperatures, 28° and 32° C. Many plants on which rotting areas were found were not inferior in growth or vigor to the unrotted plants. This was particularly true of the plants grown at temperatures below 28° C. In the lots grown at temperatures of 28° and 32° C. plants which showed wilting and tip burn at two-and-one-half to three weeks of age frequently were observed to show improvement at the end of four weeks. When taken up for examination the mesocotyls of these plants were found to be completely rotted off. The recovery of the plants was to be attributed to the appearance of the permanent roots from the lower nodes.

The results reported in Table II agree very well with those secured by Stover (18). But owing to the fact that Stover could not reisolate *F. moniliforme* from the infected tissues in all cases, and that other fungi were almost always present in such tissue, he did not consider the pathogenicity of *F. moniliforme* to be satisfactorily established. In the experiments reported above *F. moniliforme* was reisolated from diseased tissue in nearly all cases when plated. From this evidence there seems to be little doubt that *F. moniliforme* can cause serious injury at temperatures above 28° C. when other conditions are favorable. It also would appear that *F. moniliforme* is more virulent in sterile soil. Whether this is constant and whether it is due to biologic, chemical, or physical factors remains to be determined.

It was strongly suggested that the death or survival of infected plants depends upon the speed of the fungus in destroying or cutting off the temporary root system before the permanent roots begin to function. Referring again to the work of Stover (18) and Henry (5) we find the optimum temperatures for growth of this fungus in culture are given as 26°–33°C. respectively.

In searching for statistics on soil temperatures of the corn belt states it was found that there are few available. Swezey (19) at Lincoln, Nebraska, recorded the soil temperature through a period of twelve years. His tables show that at Lincoln the maximum temperature of the soil at a depth of three inches, during May, exceeded 26° C. only three times in twelve years. The mean temperature lay between 15°–24° C. For June the maximum ranged from 23.3°–40.5° C. and the mean from 19.5°–31° C. These are day temperatures. The night temperatures are lower, often by as much as 5°–8° C. If these statistics are representative of the corn belt, it appears that only on occasional years would soil temperature favor serious corn seedling injury due to *F. moniliforme*.

CONCLUSIONS.

It is clearly shown that *F. moniliforme* may grow parasitically within the growing stalk, but no effects, shown by broken and leaning stalks, are produced when infection occurs as late as August. No data as to the effect of earlier inoculation was secured.

The inoculation of ears demonstrates that this organism may grow externally on the kernels when moisture conditions are favorable. The area infected externally is usually very limited. The resistance to external molding of the kernels is greater when they have passed the dough stage.

As the possible cause of a seedling blight of corn its relations are interesting. It is present in a high percentage of Ohio seed corn. It was also isolated from the soil. But that it is an organism producing serious injury to corn seedlings at the normal soil temperatures for May and early June could not be demonstrated. The characteristic lesions produced by *F. moniliforme* on the mesocotyls are small, oval, yellowish areas, with a darker spot in the center in old lesions. On the roots the lesions are usually darker. At temperatures of 24° C. small rotted areas may be produced on the mesocotyl, usually close to the seed. At temperatures above 28° C. serious injury may occur.

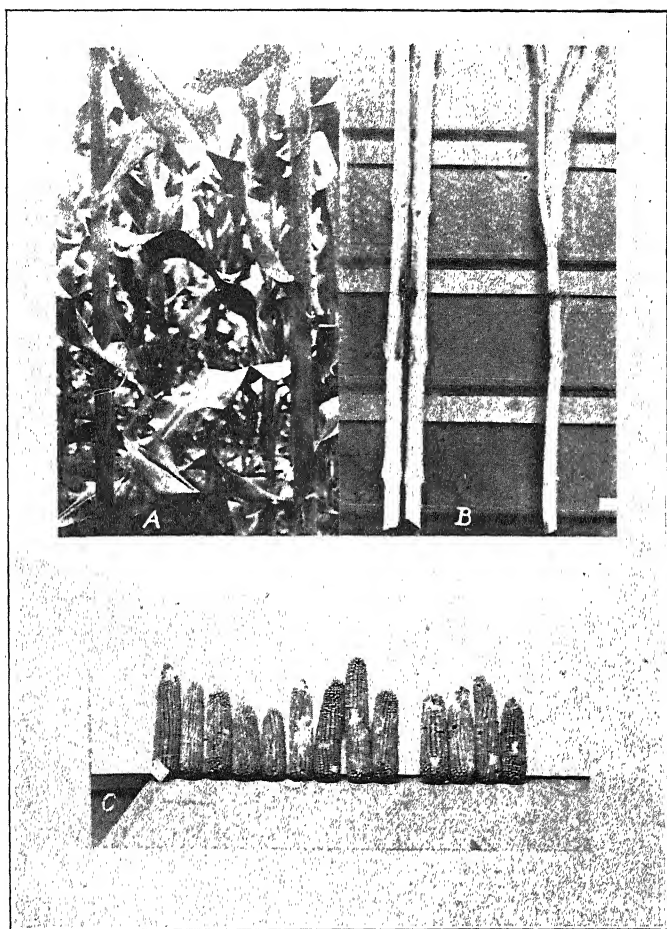
Soaking the seed in mercuric chloride for two hours at room temperature or for ten minutes at 55° C. will completely disinfect lightly infected seed. No seed treatment was found which would give perfectly clean seed when infection was heavy.

The hot mercuric chloride treatment of seed retards germination a little, but apparently causes no real injury.

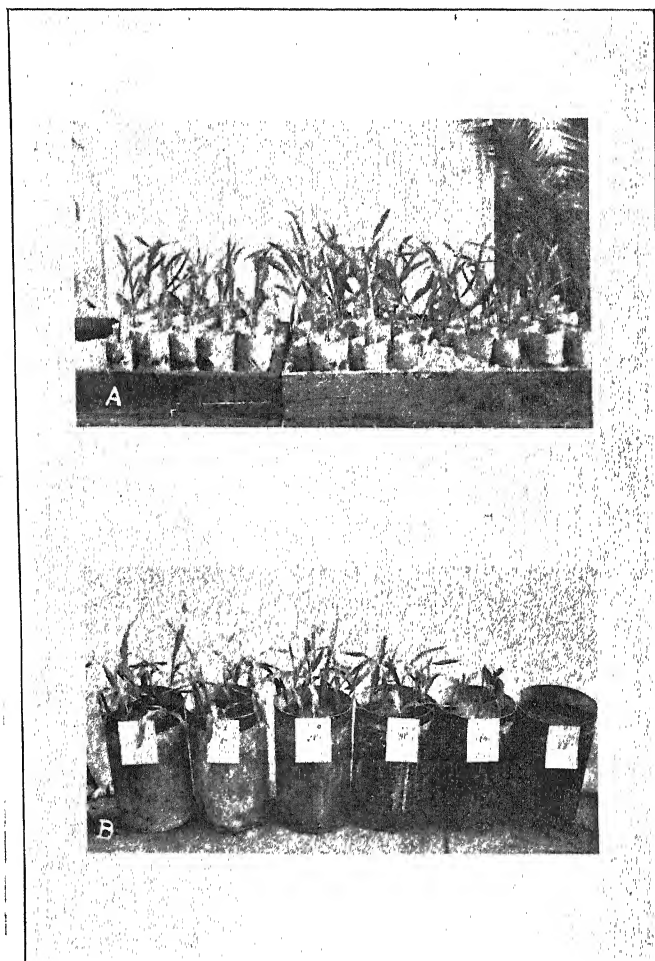
LITERATURE CITED.

1. BRANDSTETTER, B. B.
1922. Fungi internal of Missouri seed corn in 1921. *In Jour. Amer. Soc. Agron.* 14:354-357.
2. BURRILL, T. J., AND BARRETT, JAMES T.
1909. Ear rots of corn. *Ill. Agr. Exp. Sta. Bul.* 133, 109 p., 11 pl.
3. DUGGAR, B. F., AND DAVIS, A. W.
1919. The use of hypochlorites. *In Annals Mo. Bot. Gard.*, v. 6, no. 2, p. 159-170.
4. HARTLEY, CARL, MERRILL, T. C., AND RHOADS, ARTHUR S.
1918. Seedling diseases of conifers. *In Jour. Agr. Research*, v. 15, no. 10, p. 521-558, 1 pl.
5. HENRY, A. W.
1923. The pathogenicity of *Fusarium moniliforme* Shel. on cereals. (Abstract). *In Phytopathology*, v. 23, no. 1, p. 52.
6. HOFFER, G. N., AND CARR, R. H.
1923. Accumulation of aluminum and iron compounds in corn plants and its probable relation to root rots. *In Jour. Agr. Research*, v. 23, no. 10, p. 801-823, 21 pl. Literature cited, p. 822-823.
7. HOFFER, G. N., JOHNSON, A. G., AND ATANASOFF, D.
1918. Corn-root rot and wheat scab. *In Jour. Agr. Research*, v. 24, no. 13, p. 611-612.

8. HOLBERT, J. R., AND HOFFER, G. N.
1920. Control of the root, stalk, and ear rot diseases of corn. U. S. Dept. Agr. Farmers' Bul. 1176, 24 p., 25 fig.
9. JONES, L. R.
1921. Experimental work on the relation of soil temperature to disease in plants. In Trans. Wis. Acad. Sci., Arts, and Letters 20: 433-459, illus.
10. MANNS, T. F., AND ADAMS, J. F.
1921. Prevalence and distribution of fungi internal of seed corn. In Science N. S., v. 54, no. 1399, p. 385-387.
11. MANNS, T. F., AND ADAMS, J. F.
1923. Parasitic fungi internal of seed corn. In Jour. Agr. Research, v. 23, no. 7, p. 495-524, 13 pl. Literature cited.
12. MELCHERS, L. W., AND JOHNSON, C. O.
1923. Corn root, stalk, and ear rot investigations in Kansas. (Abstract). In Phytopathology, v. 12, no. 1, p. 52.
13. PAMMEL, L. H., KING, C. M., AND SEAL, J. L.
1916. Studies on a *Fusarium* disease of corn and sorghum. Iowa Agr. Exp. Sta. Research Bul. 33, 136 p., 15 fig.
14. ROSEN, H. R.
1919. A bacterial root-rot of field corn. Ark. Agr. Exp. Sta. Tech. Bul. 162, 7 p., 4 pl. Bibliography, p. 6.
15. SHELDON, JOHN L.
1904. A corn mold. In Neb. Agr. Exp. Sta. 17th Ann. Report, p. 23-32, 1 pl.
16. SHERBAKOFF, C. D.
1922. *Fusaria* of wheat and corn. (Abstract). In Phytopathology, v. 12, no. 1, p. 45.
17. SHERBAKOFF, C. D.
1924. Common molds of corn seed in relation to yield. (Abstract). In Phytopathology, v. 14, no. 1, p. 46.
18. STOVER, W. G.
Relation of soil temperature to the development of certain fungous seedling blights of corn. Unpublished paper.
19. SWEZEY, G. D.
1903. Soil temperatures at Lincoln, Nebraska. In Neb. Agr. Exp. Sta., 16th Ann. Report, p. 95-102.
20. VALLEAU, W. D.
1920. Seed corn infection with *Fusarium moniliforme* and its relation to the root and stalk rots. Ky. Agr. Exp. Sta. Research Bul. 226, 51 p. Literature cited, p. 51.
21. WINELAND, GRACE O.
1923. The production in culture of the ascigerous stage of *Fusarium moniliforme*. (Abstract). In Phytopathology, v. 13, no. 1, p. 57.



- A. General appearance of plants inoculated in the young stalk. Left, inoculated plant. Right, control. Photo taken about two weeks after inoculation.
- B. Stalks inoculated in the manner shown in "A" split for examination. Inoculated stalk at the left; check at the right.
- C. The nine ears on the left were inoculated by spraying with a spore suspension through a slit in the husks; the four on the right by inserting *F. moniliforme* growing on an apple twig or sweet clover stem into a cavity made in the cob.



- A. These plants show method of individual potting described under Seedling Inoculations. Tray at left contains control plants; right tray, the treated inoculated and naturally infected inoculated plants.
- B. A series of treated inoculated plants from the soil temperature experiments. Note the weakness of the stalks at temperatures of 28 and 30 degrees C., shown by leaning.

PRINCIPLES OF PLANT TAXONOMY, IV.*

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If the subkingdoms are properly delimited and if one has a knowledge of the general characters and the life histories of plants and if it is evident that a class should be the largest definitely determinable, monophyletic group in a subkingdom, then it becomes possible to establish such groups on a rather substantial foundation. In dividing plants into classes some attention should be given to the practical side of the problem. Each class should stand for some prominent segregative character or group of characters. At present 50 classes are recognized, several of which have only fossil members.

There is some difficulty in finding appropriate names for all the classes. All class names should be descriptive terms ending in *æ*, as Ascomycetæ, Hepaticæ, Coniferæ, Dicotylæ. At present such terms are not available for many of the class groups, and the writer, although originally equipped with a classical education, has up to the present time not found it agreeable to manufacture such names by the wholesale. Generic derivatives and older group names with the ending *ea* have, therefore, been continued. All terms which necessarily have their endings in *i* or *es* have been discarded, for, as Saccardo pointed out, Ascomycetæ means "Plantæ Ascomycetæ" and it is improper to write the term Ascomycetes unless one is intending to use the English form. But the ending *ea* is properly a tribe ending and must finally be discarded in class names.

Below, the classes of each subkingdom are segregated and defined, each one being followed by its proper number as it will stand in the phyletic system.

I. PROTOPHYTA. 3000 species. Plants giving no definite indication of a sexual nature.

SCHIZOMYCETÆ (1). Bacteria. 1350 species.

Simple unicellular or filamentous, fission fungi, parasitic, saprophytic or holophytic; non-motile or commonly with flagella or cilia,

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sometimes moving by means of cell contraction; nuclei primitive; often producing non-motile spores which can endure great extremes of heat and cold; cell division in one, two, or three directions; cells not naked nor amoeboid.

MYXOSCHIZOMYCETÆ (2). Slime-bacteria. 24 species.

Unicellular fission fungi with a slight, undulatory motion produced by the contraction of the cell, imbedded in a pseudo-plasmodium and moving about in a mass; forming peculiar sporangium-like bodies when passing into the resting or spore stage; cells not amoeboid. Saprophytes on decaying organic matter, like wood, straw, and manure.

CYANOPHYCEÆ (3). Blue-green Algæ. 1,000 species.

Nonsexual algæ with phycocyanin, blue-green or brownish in color; unicellular, in colonies, plates, or masses, or in simple or branched, undifferentiated or differentiated filaments; cells with simple nuclei and primitive chromatophores; reproduction by simple fission or by hormogones, sometimes with special resting cells; cell wall usually gelatinous. Typically fresh-water plants, frequently occurring in hot springs, some growing in aerial conditions on soil, rocks and trees.

GLAUCOCYSTEÆ (4). Higher Blue-green Algæ. 20 species.

Blue-green algæ with highly differentiated chromatophores and nuclei with nuclear membrane; unicellular or in colonies, the cells dividing in one direction. In water, on submerged Sphagnum, in salt marshes, and on wet limestone.

AUTOSPORÆ (9). Primitive Green Algæ. 200 species.

Simple, nonsexual, green algæ, unicellular, colonial, or filamentous, with reproduction by simple division or usually by autospores; cells normally with one nucleus, the nucleus with nuclear membrane. Mostly fresh-water or aerial plants.

ARCHEMYCETÆ (10). Primitive Fungi. 200 species.

Simple, parasitic, often aquatic fungi without or with a very imperfect filamentous development; nonsexual, with zoospores or with thick-walled resting spores; zoospores usually penetrating into and developing in a cell of the host plant. Commonly growing in pollen-grains in water or in algæ, and occasionally in the leaves, stems, or roots of higher plants.

II. NEMATOPHYTA. 80,000 species. Plants with sexuality, rarely showing a complete loss of this condition, with various types of life cycles, but not with a typical antithetic alternation of generations having a parasitic sporophyte.

ACRASIEÆ (5). Primitive Slime Molds. 10 species.

Saprophytic, unicellular plants without chlorophyll, with an imperfect plasmodium of aggregated cells, the cells not fused together into a continuous mass; zoospores absent, spore masses without a covering wall. Plants showing some resemblance to the Rhizopoda and usually growing on the excrement of animals.

MYXOMYCETÆ (6). Slime Molds. 350 species.

Unicellular, saprophytic, terrestrial fungi with primitive sexuality, occurring in plasmodial masses of more or less completely fused amoeboid cells which finally, with few exceptions, build up complex sporangium-like bodies or fructifications containing the spores; apparently with a simple haploid sexual cycle, the conjugation of nuclei taking place in the plasmodium at the time of the formation of the sporangium, the reduction division at the time of the formation of the resting spores; resting spores on germination giving rise to flagellate or amoeboid cells. Commonly on decaying wood and other dead organic matter.

CHLOROCOCCEÆ (11). 250 species.

Simple, unicellular or colonial, sexual algæ with free zoospores or with ciliated cells united into colonies, usually green in color, but sometimes with other pigments; usually with normal cells containing one nucleus, rarely somewhat cenocytic, the colonial forms not produced by symmetrical aggregation of free zoospores. Reproduction by division, by zoospores and by free-swimming gametes, or by motile spermatozoids and stationary oospheres.

HYDRODICTYÆ (12). 30 species.

Green cenocytic algæ growing in fresh water, consisting of colonies of peculiar form, often very symmetrical; sexual reproduction by the conjugation of equal motile gametes; nonsexual reproduction by zoospores which form the new colonies by symmetrical aggregation within the walls of the parent cenocyte or which are discharged together, enclosed in a delicate membrane.

DIATOMEÆ (7). Diatoms. 5,700 species.

Single-celled or somewhat filamentous algæ, usually of a brownish color, in which the cell wall becomes silicified and consists of two valves usually with fantastic markings or projections; reproduction by division or by the conjugation of two cells; the nonsexual forms probably degenerate. Marine and fresh-water plants of great abundance.

CONJUGATÆ (8). 2,300 species.

Unicellular or filamentous, normally unbranched and unattached, mostly fresh-water, green algæ with a single nucleus and with one or more highly specialized chloroplasts with pyrenoids in the cells; reproduction by division and by zygospores formed by the conjugation of two similar or nearly similar cells, often joined by the development of a special conjugation tube; aplanospores and parthenospores also frequently present.

SIPHONOCLADEÆ (13). Lower Tube Algæ. 450 species.

Cenocytic, filamentous, mostly septate and attached, green algæ with chloroplasts forming a net or rarely in separate plates; usually branched, isogamous or heterogamous, fresh-water or marine plants.

SIPHONÆ (14). Higher Tube Algæ. 200 species.

Cenocytic, terrestrial, fresh-water, or marine, green algæ, usually filamentous, simple or branched, usually attached, and usually without

transverse septa in the vegetative parts; reproduction by zoospores, by ciliated gametes, or by true sperms and eggs; chloroplasts distinct, oval, lenticular, or plate-like.

MONOBLEPHARIDÆ (15). 6 species.

Small, cenocytic fungi with transverse septa, with unciliated zoospores and with a typical sexual reproduction; saprophytic and aquatic; eggs stationary in the oogonia, which open to admit the free-swimming unciliated spermatozoids.

CONFERVEÆ (16). Confervas. 650 species.

Simple or branched, filamentous, green algæ having normal cells with one nucleus; sometimes with the cells in disks or sheets; usually attached; reproduction by means of zoospores and by motile iso-gametes or by hetero-gametes, the eggs being stationary; chloroplasts one or more, usually with pyrenoids; mostly growing in fresh water.

PHAEOSOPRÆ (17). Little Kelps. 550 species.

Normally brown-colored, marine algæ ranging from quite simple, filamentous forms to rather large organisms, usually attached; reproduction by zoospores produced in unilocular sporangia and by motile gametes produced in plurilocular gametangia; both types of sporangia exposed.

CYCLOSOPRÆ (18). Rockweeds. 350 species.

Medium-sized to large, marine, brown algæ; attached, branched, and usually flat or flattish; reproduction by small biciliated sperms and large nonciliated eggs which are discharged and fertilized in the water; reproductive organs sunken in conceptacles; zoospores absent; with a simple diploid sexual cycle.

LAMINARIÆ (19). Giant Kelps. 100 species.

Large and highly developed, marine, brown algæ, with a distinct conducting tissue whose cells contain sieve-plates; frond usually prominently differentiated into holdfast, stalk, and leathery leaf-like structures; with an alternation of generations, the nonsexual spores (zoospores) produced in unilocular sporangia and giving rise to minute, filamentous, haploid, male and female gametophytes; sporophytes probably diploid; gametangia unilocular.

DICTYOTÆ (20). 130 species.

Erect, attached, marine, brown algæ with flat leaf-like fronds and with an alternation of generations; nonsexual reproduction by non-motile tetraspores; sexual reproduction by means of non-ciliated eggs, produced singly and finally discharged from the ogonium, and sperms with one flagellum, produced in many-celled antheridia.

MONOSPORÆ (21). 50 species.

Marine or fresh-water, red or purple algæ with filamentous or thalloid fronds; reproduction by single thallus cells and by the production of antheridia and oogonia from ordinary thallus cells, the antheridium developing nonciliated sperms, the oogonium, which is without a distinct trichogyne, usually developing a single, stationary egg.

FLORIDEÆ (22). 3,000 species.

Mostly marine, red or purple algæ, often of considerable size, filamentous or thalloid; reproduction by means of non-ciliated sperms produced in antheridia consisting of definite groups of cells, and eggs produced singly in the base of an oogonium which is prolonged above into a slender trichogyne. Plants with a definite alternation of generations, the fertilized egg having a complicated development, but in the simpler cases giving rise to a juvenile sporophytic body from which one to many carpospores are produced which on germination develop into a second sporophytic stage on which tetraspores are produced, following a reduction division, from which the gametophyte is again propagated.

CHAREÆ (23). Stoneworts. 160 species.

Green, erect, filamentous, mostly fresh-water algæ attached at the base by rhizoids; stems distinctly segmented into nodes and internodes, the nodes being marked by whorls of branches; plants usually with an incrustation of lime and the cells of the stem and branches often covered with a cortical layer of smaller cells; with a simple diploid sexual cycle; oogonia rounded, covered by a cortical layer of spiral branches; antheridia compound and very complex, composed of united branches to form a hollow, globular structure containing sperm-bearing filaments; spermatozoids spirally coiled, biciliated; nonsexual spores absent.

ZYGOMYCETÆ (24). 180 species.

Saprophytic or parasitic fungi with a nonseptate or nearly nonseptate mycelium having a conjugation of equal or nearly equal branches, one of which does not penetrate the other to any extent, the result of the conjugation being a simple or cenocytic zygospore; sometimes parthenogenetic; nonsexual spores nonmotile.

OOMYCETÆ (25). 185 species.

Mostly parasitic fungi with a nonseptate or nearly nonseptate mycelium, with conjugating branches, the one being much larger than the other which penetrates into its interior, or empties its contents into the larger, the result being a simple or cenocytic sexual spore; sometimes parthenogenetic; nonsexual, motile spores also produced which frequently develop in conidia.

ASCOMYCETÆ (26). Sack Fungi. About 18,000 typical species, besides 1,500 Lichens and 13,000 Deuteromycetæ.

Parasitic, helotic, or saprophytic fungi with a septate mycelium, the cells being uninucleate; and with asci usually containing a definite number, often eight, of ascospores, the asci produced as the result of a conjugation of two branches or cells of the mycelium, or apparently commonly through a more complicated sexual process with a binucleate-cell phase or conjugate generation prominently developed and ending in a true diploid nucleus which represents the zygote. The diploid nucleus on dividing undergoes reduction and by subsequent divisions the ascospores are formed; conidiospores commonly developed, in many groups the conidial stage only being known.

LABOULBENIÆ (27). Beetle Fungi. 500 species.

Minute fungi with a septate body parasitic upon insects, usually beetles, connected with the host by means of a dark-colored, horny base serving as an organ of absorption and a holdfast; oogonium with a slender projection, the trichogyne, to which the nonmotile spermatia became attached and finally fertilize the oosphere below; as the result of fertilization a number of sacs or asci are produced which contain the ascospores.

TELIOSPORÆ (28). Brand Fungi. 4,000 species.

Parasitic fungi with the septate mycelium developed in the tissues of the host, finally producing teliospores which on germinating give rise to septate or nonseptate basidia on which basidiospores are developed; some groups producing five kinds of spores; often heterecious; conjugate phase or generation with binucleate cells prominently developed and often reproducing itself by binucleate spores. Plants especially abundant on species of the grass family.

BASIDIOMYCETÆ (29). Basidium Fungi. 14,000 species.

Mostly large, saprophytic, sometimes parasitic fungi with a septate mycelium; developing septate or nonseptate basidia on the fruiting body or on the vegetative mycelium, not on special teliospores; basidia usually with four spores; conjugate phase prominent and the binucleate cells on dividing developing clamp-connections.

III. BRYOPHYTA. 17,000 species. Nonvascular plants with a continuously dependent sporophyte.

HEPATICÆ (30). Liverworts. 4,000 species.

Gametophyte thalloid or a stem-like frond with scales which are without a costa, mostly dorsiventral, usually with a sack-like envelope, the perigynium, around the archegonia; rhizoids threadlike and unicellular; protonema usually small or only slightly developed, transient. Sporophyte either a spherical sporangium without foot or stalk, or differentiated into a sporangium, foot and elastically elongating stalk; sporangium without columella, usually with elaters, indehiscent, irregularly dehiscent at the top, or splitting into four valves from the summit, rarely developing an operculum.

SPHAGNEÆ (31). Bog-mosses. 380 species.

Gametophyte a stem-like, erect, light, gray-green frond without a true central strand, but with large cortical cells, bearing numerous scales without a costa but with two kinds of cells, narrow ones with chlorophyll and large ones without, but commonly with holes in the walls and with spiral fibrils; rhizoids septate; protonema finally thalloid and flat; fruiting plant developing one or more pseudopodia which support the stemless sporophytes. Sporophyte with an expanded foot; sporangium with a shallow, dome-shaped spore-cavity in the upper part and with an operculum but without a peristome, elaters, or air cavities. Growing in bogs and wet places.

SCHIZOCARPÆ (32). Granite-mosses. 105 species.

Gametophyte a stem-like, erect frond without a central strand, bearing numerous scales without or with a costa; rhizoids consisting of cylindrical masses or plates of cells; protonema more or less thalloid. Sporophyte without a seta, but with a foot and finally carried upon a pseudopodium; sporangium without air cavities, splitting into four or more valves which are at first united at the top; spore-cavity cylindrical dome-shaped with an upward projecting central columella; elaters none; calyptra present on the sporophyte. Caespitose plants of a dark brown color growing on rocks.

ODONTOCARPÆ (Musci) (33). Mosses. 12,500 species.

Gametophyte a stem-like, erect or prostrate frond, usually with a well-developed central strand and usually with costate scales; rhizoids filamentous, septate; protonema usually well-developed and filamentous, sometimes persistent; pseudopodium none. Sporophyte well-developed, with sporangium, foot, and usually with a well-developed hypophysis, and a seta with a central strand; sporangium usually with an operculum and a central columella extending entirely through the spore cavity, usually with a well-developed peristome and air spaces often communicating on the outside with true stomata; venter of the archegonium enlarging and usually ruptured at the base, the upper part being carried on top of the sporangium as the calyptra.

ANTHOCEROTÆ (34). Hornworts. 105 species.

Gametophyte a dorsiventral, thalloid frond without scales or with imperfectly developed scales but with unicellular rhizoids; sexual organs imbedded in the tissue of the thallus; protonema small and transient. Sporophyte with a slender horn-like or pod-like sporangium and with a bulbous foot containing an irregular surface with wart-like projections; sporangium with a central columella, two-valved, with small irregular elaters among the spores; epidermis with or without stomata; cells mostly with a single large chloroplast; intercalary growth present between the foot and sporangium.

IV. PTERIDOPHYTA HOMOSPORÆ. 7000 species. Homosporous vascular plants in which the sex is determined in a haploid cell of the gametophyte.

PHYLLOPTERIDÆ (Filices) (35). Ferns. 6500 species.

Sporophyte herbaceous or tree-like, indeterminate in growth, usually with a horizontal, simple or branched rhizome; leaves usually large, spirally arranged, and mostly compound, rarely narrow and grass-like; sporangia borne on the underside of the leaf, or on the morphologically upper side on simple or branched sporangiophores; eusporangiate or leptosporangiate, with or without indusia; sporophylls never in cones. Gametophyte comparatively large, tuber-like, without chlorophyll and subterranean, or usually developed as a flat, simple or rarely branched thallus, usually hermaphroditic but unisexual in some of the higher forms; spermatozoids multiciliate.

SPHENOPHYLLÆ (38). Fossil.

Paleozoic plants of moderate dimensions with solid, jointed stems with a central, triarch vascular bundle; leaves mostly wedge-shaped, comparatively small; sporophylls in cones.

EQUISETÆ (39). Horsetails. 25 species.

Sporophyte perennial, herbaceous, with a rhizome and with jointed, mostly hollow, simple or branched, annual or perennial, aerial stems; vascular bundles in a circle; leaves reduced to sheaths around the joints, the sheaths toothed; cones terminal with small peltate sporophylls arranged in whorls; sporangia sack-like, eusporangiate; lowest whorl of the cone of united segments developing sporangia on the upper side in the lower species but forming a sterile calyx in the highest; spores with 4 narrow, strap-like, spiral, hygroscopic appendages formed from the outer wall. Gametophyte a small green thallus hermaphroditic or unisexual with frequent sex-reversal; spermatozoids multiciliate.

LYCOPODIÆ (41). Lycopods. 160 species.

Sporophyte perennial, herbaceous, with or without a rhizome the aerial stems upright or trailing; branching dichotomous; leaves small, without a ligule, spirally arranged on the stem, two-to many-ranked; sporangia solitary on the upper surface of the leaves or in their axils, sometimes trilocular, eusporangiate; sporophylls in bands or zones alternating with the foliage leaves or arranged in terminal cones; spores small, not appendaged. Gametophyte small, sometimes subterranean, with or without chlorophyll, hermaphroditic; spermatozoids small, biciliate.

V. PTERIDOPHYTA HETEROSPORÆ. 800 species. Seedless plants with two kinds of nonsexual spores, the sex being determined in a diploid cell of the sporophyte.

ISOETÆ (36). Quillworts. 64 species.

Sporophyte with a short, tuberous stem with a peculiar type of secondary thickening and with long, erect, grass-like leaves which have a ligule; roots dichotomous; microsporangia and megasporangia large, borne singly, sunken in the upper side of the expanded bases of the leaves, eusporangiate. Gametophytes very much reduced, unisexual; spermatozoids large, spirally coiled, multiciliate.

HYDROPTERIDÆ (37). Water-ferns. 75 species.

Sporophytes small with a horizontal rhizome or floating on the surface of the water; leaves alternate or whorled; internodes mostly well-developed; microsporangia and megasporangia borne together on the same leaf, enclosed in true sporocarps or apparent sporocarps, leptosporangiate. Gametophytes developing entirely within the spore walls or protruding only slightly, very short-lived; spermatozoids large spirally coiled, multiciliate.

CALAMARLÆ (40). Calamites. Fossil.

Paleozoic plants, sometimes of tree-like aspect and dimensions, with hollow, jointed stems and with a circle of collateral bundles; stems increasing in diameter by a cambium zone; heterosporous, the sporophylls in cones.

SELAGINELLEÆ (42). Selaginellas. 600 living species.

Small herbs or many of the fossil forms large trees. Sporophytes of living species erect, or ascending, or sometimes creeping and dorsiventral, with dichotomous stems and dichotomous roots; leaves small spirally arranged or sometimes opposite, ligulate; cells often with a single chloroplast; sporophylls in bisporangiate cones, the eusporangiate microsporangia and megasporangia single on the base of the upper side of the sporophylls. Gametophytes minute and short-lived; spermatozoids minute, biciliate. Some fossil species developed into large trees with secondary thickening by a cortical meristem and with a dichotomous branching system developed at the base as well as at the top of the stem, apparently being the first sporophytes with a successful basal growth.

VI. GYMNOSPERMÆ. 500 living species. Seed plants with open carpels.**PTERIDOSPERMÆ (43).** Fossil.

Paleozoic seed-plants of fern-like aspect; stems short and usually erect, increasing in thickness and bearing mostly compound leaves.

CYCADEÆ (44). Cycads. 95 living species.

Sporophyte with erect, often woody, simple or little-branched stems or occasionally geophilous, bearing compound leaves; vascular bundles collateral, increasing in thickness by their cambiums; cortical meristems developed in some species in which new circles of bundles are produced; sporophylls in cones or the carpels sometimes merely in zones through which the stem grows; living species diecious; ovules with pollen-chambers; embryo with 2 cotyledons, rarely one. Female gametophyte becoming large and fleshy; male gametophyte, or pollengrain developing two or more large, spirally coiled and multiciliate spermatozoids.

CORDAITEÆ (45). Fossil.

Paleozoic, sparsely branched trees bearing large, long, parallel-veined leaves spirally arranged.

GINKGOÆ (46). Maiden-hair-trees. 1 living species.

Sporophytes developing into large trees with a cambium layer from which annual rings of wood are produced, with a crown of numerous branches of two types, long branches with internodes and dwarf branches without, with spirally arranged, broad, dichotomously veined, deciduous leaves, and without flowers but with zones of sporophylls on some of the dwarf branches; ovule with pollen-chamber; cotyledons 2; the embryo sometimes not developing until the seed drops to the ground. Female gametophyte becoming large in the seed which has a bony inner and a fleshy outer coat; male gametophyte developing 2 large, spirally coiled, multiciliate spermatozoids.

CONIFERÆ (47). Conifers. 350 species.

Sporophytes developing as large trees or shrubs, much branched, with or without dwarf branches; stems with a normal cambium, no vessels in the secondary wood, resin commonly present; leaves mostly small, scale-like, linear, or needle-like, rarely broad; flowers monosporangiate, monocious or diecious, the higher types much reduced; cotyledons 2-15; ovule without pollen-chamber. Female gametophyte usually comparatively small; pollengrains sometimes winged, producing two non-motile sperms.

GNETEÆ (48). 50 species.

Sporophytes developing as shrubs or lianas, or rarely as trees, with branched or rarely simple stems; secondary wood containing vessels representing enlarged tracheids; leaves simple, opposite or whorled, sometimes reduced to dry bracts but often large; flowers monocious or mainly diecious, collected in specialized inflorescences; resin passages none; cotyledons two. Gametophytes small, various in character, the sperms not motile.

VII. ANGIOSPERMÆ. 150,000 species. Seed plants with closed carpels and with stigmas; xeniophyte usually present.

MONOCOTYLÆ (49). Monocotyls. 25,000 species.

Sporophytes developing as herbs or sometimes as woody plants of large dimensions; embryo usually with one terminal cotyledon and usually with a lateral plumule; stem with closed, usually scattered vascular bundles, without typical bark and without annual rings of growth, rarely with secondary thickening; leaves mostly parallel-veined, sometimes netted-veined; flowers mostly of the trimerous and typically of the pentacyclic type.

DICOTYLÆ (50). Dicotyls. 125,000 species.

Sporophytes developing as herbs or woody plants; embryo with two cotyledons, rarely with more or with only one, and with a terminal plumule; stem with open vascular bundles, usually arranged in a circle and developing a continuous cambium cylinder, forming annual rings of growth in the case of perennial stems, with bark on the outside; leaves usually netted veined; flowers more commonly pentamerous or tetramerous, the higher types usually tetracyclic.

SYNOPSIS OF THE PLANT PHYLA AND SUB-PHYLA.

It is possible, in a vague way, to see monophyletic relationships among certain classes. These apparently related classes can then be combined into convenient larger groups, the Phyla. The phyla represent the largest taxonomic groups.

In establishing phyla, regard should be had for convenience and practical usability as in the case of the classes. Most

systematists would probably agree that all the META-THALLOPHYTA are monophyletic as compared with the THALLOPHYTA. This is no reason, however, for establishing such a complex system as a single phylum in contrast to numerous phyla in the Thallophyta as is sometimes done. It is evident that from the evolutionary point of view, all the Thallophyta have also come from a common source and are in this sense monophyletic. The aim should be to segregate great branches or groups of somewhat similar value and importance. It seems to the writer that about 15 main groups will make a satisfactory system, although he has no quarrel with any one who thinks there should be several more, so long as the groups are practical and of more or less equal value.

-
- I. Plant body unicellular, colonial, or multicellular, frequently filamentous; ovary when present never an archegonium; nonsexual plants or with a simple haploid or a simple diploid sexual cycle, sometimes with haploid and conjugate phases, the conjugate phase with binucleate cells, sometimes with an alternation of haploid and diploid generations, but then not of the typical antithetic type, the diploid sporophyte never having a parasitic existence or proper parasitic phase on the parent gametophyte, but originating from a free spore or zygote. (THALLOPHYTA).
 - A. Cells typically with poorly differentiated nuclei and chromatophores and with a primitive type of nuclear division; motile or nonmotile, with or without chlorophyll, never with a pure chlorophyll-green color; reproduction by fission; resting spores or cells commonly present. Phylum I. SCHIZOPHYTA. 1, 2, 3, 4.
 - B. Cells with well differentiated nuclei and if holophytic usually with definite chloroplasts; with or without chlorophyll; plants green or colorless or variously tinted by coloring matter other than chlorophyll.
 - (A). Unicellular saprophytic plants without chlorophyll, having a plasmodium stage of more or less completely fused cells, mostly amoeboid in nature, from which complex sporangium-like resting bodies are built up; sexuality primitive, consisting of the conjugation of nuclei in the plasmodium at the time the sporangia develop; resting spores finally liberating flagellate or amoeboid cells. Phylum II. MYXOPHYTA. 5, 6.
 - (B). Plants not developing a plasmodium, the cells usually covered with a wall during the vegetative phase.
 1. Unicellular or filamentous plants containing chlorophyll, either brown and with silicious, two-valved walls or green with complex chromatophores and the walls not silicified; conjugating cells not ciliated, isogamous; with a simple haploid sexual cycle, the reduction division probably always in the zygote. Phylum III. ZYGOPHYTA.
 - a. With silicified cell walls and brown coloring matter. Subphylum and class 1. DIATOMÆ. 7.
 - b. Not with silicified walls; cells green. Subphylum and class 2. CONJUGATÆ. 8.

2. Plants not with silicified two-valved walls; either nonsexual or isogamous or heterogamous; if with a direct conjugation of walled cells or branches then without chlorophyll.

(1). Plants with chlorophyll, or if without chlorophyll, then either without a true mycelium, or if a mycelium-like filament is present then with a sexual phase with ciliated, motile spermatozooids and stationary eggs.

- a. Antheridium when present not consisting of a globular structure containing sperm-bearing filaments.

(a). Plants usually green, with chlorophyll or colorless, nearly all producing nonsexual zoospores; unicellular, colonial, or multicellular, nonsexual or mostly sexual plants, the sexual forms isogamous or heterogamous; nearly all with simple, haploid, sexual cycle, but some apparently with a simple, diploid, sexual cycle.

Phylum IV. GONIDIOPHYTA. 9, 10, 11, 12, 13, 14, 15, 16.

- (b). Plants with the chlorophyll usually hidden by a brown, red, or purple pigment, always with a multicellular body and sexuality.

((a)). Mostly marine brown algae with phyco-phaein; isogamous or heterogamous with ciliated sperms, both gametes usually discharged from the gametangia; with a simple, diploid, sexual cycle, perhaps some also with a simple, haploid sexual cycle, or in the higher forms with two or more types of the alternation of generations cycle.

Phylum V. PHAEOPHYTA. 17, 18, 19, 20.

- ((b)). Mostly marine red or purple algae with phyco-erythrin; heterogamous, with stationary eggs and nonciliated sperms; apparently normally with an alternation of generations.

Phylum VI. RHODOPHYTA. 21, 22.

- b. Filamentous, aquatic, green algae with globular antheridia containing sperm-bearing filaments, the sperms being biciliated; nonsexual spores absent; with a simple, diploid, sexual cycle, the reduction division apparently taking place in the sexual organs.

Phylum VII. CHAROPHYTA. 23.

- (2). Plants without chlorophyll and with a true septate or nonseptate mycelium; sexual reproduction without motile sperms; nonsexual reproduction of various types; with a simple, haploid, sexual life cycle, or in the higher forms with a modification of this cycle, in which a binucleate or conjugate phase follows the normal haploid phase with uninucleate cells. Phylum VIII. MYCOPHYTA.

a. Mycelium cenocytic; without ascospores or basidiospores. Subphylum I. PHYCOMYCETÆ. 24, 25.

- b. Mycelium normally not cenocytic, with ascospores or basidiospores, or apparently numerous degenerate forms in which such spores are no longer developed, but which are propagated solely by conidia.

Subphylum 2. MYCOMYCETÆ. 26, 27, 28, 29.

- II. Plant body a solid aggregate; if filamentous, only so in the embryonic or immature condition; ovary a typical archegonium or if much reduced then the plants seed-bearing; always with a typical, antithetic alternation of generations in the normal life cycle, the diploid sporophyte being parasitic during its entire life or in its embryonic phase on the sporophyte.

(META-THALLOPHYTA).

- A. Without vascular tissue; sporophyte parasitic on the gametophyte during its entire life and determinate in growth; homosporous; small plants without roots or true leaves.

Phylum IX. BRYOPHYTA. 30, 31, 32, 33, 34.

- B. Always with vascular tissue in the sporophyte which becomes an independent plant, after the embryonic phase, with roots and leaves except in a few degenerate forms; and always with decidedly indeterminate growth of all or part of the axes.

- (A). Sporophyte not seed-producing; sperms breaking out of the antheridium to enter the necks of the archegonia directly; homosporous or heterosporous, the sex being determined either in the gametophyte or in the sporophyte.

1. Spermatozoids comparative large and multiciliate; sporophylls not in cones, or in cones (strobili or primitive flowers), but then the sporophyte with jointed stems and whorled leaves; branching normally monopodial.

- a. Stems not jointed, the leaves usually large and compound and spirally arranged, rarely in whorles; sporophylls never in cones, the reproductive axes always indeterminate.....Phylum X. PTENOPHYTA. 35, 36, 37.

- b. Stems jointed and fluted, bearing whorled leaves, which in living forms and in most fossil forms are much reduced; sporophylls in cones; living species, and many fossil forms also, with some determinate vegetative branches.

Phylum XI. CALAMOPHYTA. 38, 39, 40.

2. Spermatozoids small, biciliate; leaves of the living species small, covering the continuous stem in spirals, or sometimes in opposite arrangement; rarely with a slight internodal development; branching of the stem dichotomous, the lowest species all indeterminate; sporophylls usually in cones or in the lower forms in zones alternating with the sterile leaves; frequently also with determinate vegetative branches.

Phylum XII. LEPIDOPHYTA. 41, 42.

- (B). Sporophyte producing seeds, the female gametophyte always parasitic in the megasporangium (ovule) during its entire life, the male gametophyte developing a pollen-tube through which the sperms are discharged, hence with a two-phased parasitic growth, the first stage in the microsporangium, the second in the ovule, or in the higher groups beginning in the tissues of the megasporophyll itself (carpel); with a resting stage intercalated between the two phases of the sporophyte; always heterosporous; the sex being determined in the sporophyte.

1. Carpels open, without stigmas or true ovularies, the ovules and seeds naked and the pollen-grains (male gametophytes) falling directly into the micropyle; no true endosperm or xeniophyte present.

- a. Sperms so far as known ciliated and motile; ovules with a pollen-chamber; with or without flowers, the sporophylls either being in cones, or in rosettes on indeterminate axes.

Phylum XIII. CYCADOPHYTA. 43, 44, 45, 46.

- b. Sperms without cilia; ovules without pollen-chambers; sporophylls in cones, which may be highly specialized or reduced and in the highest types collected into definite inflorescences; woody plants, monocious or diecious.

Phylum XIV. STROBILOPHYTA. 47, 48.

2. Carpels or the set of carpels closed at maturity, with stigmas and with ovularies enclosing the ovules and seeds; pollen-grains falling on the stigma and developing long pollen-tubes; flowers well developed, commonly with a perianth, often highly specialized or reduced; true endosperm or xeniophyte normally present.....Phylum XV. ANTHOPHYTA. 49, 50.

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STUDIES ON THE PHYSICAL PROPERTIES OF LEAVES AND LEAF SAPS.*†

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The ability of the leaves of certain species of plants to endure without injury temperatures below freezing for protracted periods of time is known to bear a close relation to the physico-chemical properties of the leaf cells. Recent advances in our knowledge of drought resistance seem to show that this property also may have its basis in the physiology of the leaf cells, rather than in anatomical peculiarities of the leaves. Studies of the physical properties of the cell and of the protoplasm may be expected to advance our knowledge of these phases of plant physiology. The relative drought resistance of different species of plants is an important factor in ecological distribution. The survival of the leaves of certain species of herbs, shrubs, and trees during the winter months can only be explained when the basis for frost resistance in the leaves of these species is understood. From the practical standpoint, knowledge of those physical properties which are correlated with frost and drought resistance will permit predictions regarding the suitability of various varieties of agricultural species for cultivation in localities subject to climatic extremes. If no physiological measures of relative frost or drought resistance be available, the alternative method of field tests must be used, comparatively costly in both time and money.

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The fundamental importance of the water relations of plants in determining their distribution has long been recognized. The universally accepted ecological classification of plants by Warming (53) into hydrophytes, mesophytes, and xerophytes recognizes this basis. Transeau (52), and later Livingston and Shreve (38, p. 518) have shown that the rainfall-evaporation ratio ("moisture ratio") is dominant in determining the distribution of vegetation in the United States. The physiological problem as to why certain plants are enabled to withstand the severe conditions of drought, while others will survive only when the water supply is moderate, and still others only when it is abundant, has by no means been completely solved.

The general presumption has been that the ability of the plant to conserve water in the leaves through the internal conditions operative in those leaves is the important factor in drought resistance. Livingston (37) and Bakke (4) believed that the "foliar transpiring power" was a fairly accurate index of the ability of leaves to conserve water, and hence of the water relations of the plant. "Transpiring power" is a measure of the rate of water vapor loss from leaves as controlled by internal conditions. Bakke concluded from his experimental work that this method "——— offers an apparently adequate and somewhat simple means for classifying plant forms in a scale of xerophytism or of mesophytism." Pool (47), however, in an extended investigation, found only indifferent correlation between habitat xerophytism and "transpiring power." The importance of foliar "transpiring power" as an index of relative xerophytism has apparently been overestimated by some of the pioneers in this field.

Variations in the resistance offered by leaves of different species to water vapor loss have been explained in the past principally on the basis of the anatomical features of the leaves, such as number, size, and distribution of stomata; epidermal hairs, cuticle, compactness of tissues, schlerenchyma, etc. Pool also attempted to correlate leaf structure with "transpiring power" but his work seems to show that leaf anatomy is an inadequate explanation of variations in the resistance of leaves of different species to transpirational water loss. Some structures commonly considered characteristic of xerophytic leaves may have a negligible effect upon transpiration. Sayre (49) has shown that the abundant epidermal hairs of the mullein (*Verbascum Thapsus*), for example, have no appreciable effect

in decreasing transpiration. Some plants with leaves apparently xeromorphic, such as *Ilex opaca* (holly), *Rhododendron maximum* (rhododendron), and *Cyrtomium falcatum* (holly fern), are in habitat mesophytic. On the other hand some plants will endure extreme drought whose leaves are lacking in any xeromorphic features. Such apparent anomalies may be largely cleared up by studies of the physical properties of leaves and leaf saps, and as microchemical and microphysical methods are developed, of the protoplasm.

Maximow (41) believed that the ability of the protoplasm of the leaf cells to endure the wilted condition is the essential factor in drought resistance. By the wilted condition is meant a semi-permanent diminution in the water content of the leaf cells. This is not necessarily a visible phenomenon, since in leaves with abundant ligneous tissue wilting may be obscured. According to this worker many xerophytes are known to have high transpiration rates when the water supply is favorable, while some mesophytes have low rates of transpiration. Transpiration is, therefore, not an adequate measure of relative xerophytism. The physico-chemical properties of the protoplasm and of the cell sap must be such that the protoplasm can endure or resist this deprivation of water sufficiently to prevent coagulation of the protoplasmic colloids. The problem of drought resistance, considered from this standpoint, resolves itself into a question of why the protoplasm in the leaf cells of certain species can endure the partial desiccation involved in wilting, while the protoplasm of other species cannot.

It is now generally agreed that during the formation of ice in plant tissues, water usually freezes first in the films on the outer surface of the cell walls, bounding the intercellular spaces. As the freezing process proceeds, water gradually moves from the interior of the cell into the cell walls, replacing that which was withdrawn from the walls by the process of crystallization. It is this loss of water from the cell which is the cause, directly or indirectly, of injuries accompanying the formation of ice crystals in the tissues of plants. Wiegand (54, 55) has given an excellent historical summary of the literature dealing with the formation of ice in plant tissues as a setting for his own investigations in this field. The similarity of the effects of drought and freezing on the cell are apparent; both are, from the standpoint of fundamental physiology, desiccation processes. It is probable, therefore, that some of the internal cell conditions important in drought resistance are also important in frost resistance.

The literature covering previous investigations of the causes of death during the freezing process, and of the bases of frost resistance in plants has been comprehensively reviewed by Abbe (1), Blackman (6), Chandler (7), Rosa (48), Harvey (32), and Newton (45). Only a condensed statement of the more pertinent contributions to our knowledge in these fields will be included here. Muller-Thurgau (43) and Molisch (42) believed that the injury involved in the freezing to death of a cell resulted from the withdrawal of water from the protoplasm, which resulted in its structural disorganization. Maximow (40) thought that death resulted only when the water was withdrawn from the plasma membrane. The withdrawal of water from the cell gradually concentrates the electrolytes in solution in the vacuole. Gorke (10) advanced the theory that this concentration of the electrolytes had a salting out effect on the proteins in the cell sap and protoplasm, and that this was the cause of death. Harvey (32) believed that this salting out effect is inadequate to explain the precipitation of the proteins upon the freezing of a plant juice unless the increase in the hydrogen ion concentration which accompanies a lowering of temperature is taken into consideration, as a contributing or modifying factor.

There are several conditions which may operate in the cell in such a way as to prevent injury in the freezing process. A high osmotic value of the cell sap, or a high force of imbibition in the protoplasmic colloids would tend to prevent movement of water from the cell when crystallization occurs in the intercellular spaces. Newton (45) found the latter condition to be an important factor in the frost resistance of winter hardy wheat. Disorganization of the protoplasmic complex due to the concentration of electrolytes accompanying the withdrawal of water from the cell may be prevented if the proteins have been converted to a less readily precipitated form during the hardening process (Schaffnit, 51; Harvey, 32). Accumulation of sugars in the cells exerts a protective action which checks or prevents the precipitation of proteins (Schaffnit, 51; Lidforss, 36). Maximow (40) has found that solutions of many non-toxic compounds, both organic and inorganic, which have a low eutectic point relative to the freezing point, exert a remarkable protective action on the freezing of plant tissues which are immersed in them.

This paper reports the results of an investigation upon the range of certain physical properties of leaves and leaf saps in fifty species of plants, representing many of the habitats common to central Ohio. Determinations were made of the water content of the leaves, amount of sap which could be expressed from the leaves under a standard treatment and pressure; and of the osmotic value, percent of solid matter, and colloidal content of the expressed leaf saps. One purpose of this general survey was to secure data upon the range of these physical properties in the leaves of native plants, and to discover the correlations, if any, between habitat or growth form and the physical properties of leaves. The native vegetation of Ohio presents many unsolved problems in the physiology of frost resistance, and in the physiology of relative drought resistance. It is hoped that this study may fulfill a second purpose by serving as a foundation for more detailed investigations upon some of these problems.

II.

REVIEW OF LITERATURE.

The only physical property dealt with in this paper which has been extensively studied by previous workers is the osmotic value* of the expressed leaf saps. The first critical work on the determination of the osmotic pressure of leaf saps by the cryoscopic method was that of Dixon and Atkins (8, 9) in 1913. They demonstrated the necessity of freezing or otherwise treating the leaf sample before the sap was expressed in order to obtain representative results. Their earlier work and the work of previous investigators had shown that samples of sap expressed from untreated tissues could not be regarded as typical because samples of sap successively extracted from the same tissue differed in osmotic pressure. This differential expression of the sap is almost completely eliminated if the leaf sample first be frozen.

Harris (16-30, inc.) and his collaborators have made a survey of the osmotic pressures of the expressed leaf tissue fluids of plants from a wide range of habitats. Osmotic pressures were

* A solution such as an expressed plant sap has only a potential osmotic pressure. In this paper this is termed the osmotic value. The term osmotic pressure is retained, however, when discussing the results of investigators who have used this term consistently in their writings.

calculated from the depression of the freezing point of saps expressed after freezing the tissue in an ice-salt mixture. These investigations have been important in determining the range of osmotic pressures in leaf tissue fluids. In general the expressed juices of leaves from plants growing in dry or saline habitats are higher in osmotic pressure than the leaf saps from plants growing where the moisture conditions of the soil are more favorable. Important exceptions to this generalization, the cacti for example, show the inadequacy of explanations of the water relations of plants on the basis of osmotic pressures alone. Ligneous plants, in general, have leaf saps with higher osmotic pressures than herbaceous plants. The osmotic pressure of the expressed sap of parasitic forms is generally, but not invariably, higher than that of the host plant. Epiphytes show lower osmotic pressures than terrestrial forms. Correlated studies upon the electrical conductivity of the expressed leaf saps have shown that this is higher in the tissue fluids of herbaceous species than in ligneous species.

Korstian's study (34) of the "sap densities" of plants in the Wasatch mountains of Utah and vicinity is a recent contribution in this field. The results of this investigation confirm in general those of Harris and his co-workers. Saps from herbaceous plants were found to have lower osmotic values than saps from ligneous species. The sap of shade plants showed lower values than that of sun plants of the same species. Young leaves and shoots showed lower sap concentrations than older tissues. Plants from dry or saline habitats showed a higher concentration of solutes in the expressed leaf saps than plants from habitats where the moisture conditions were more favorable. Correlated studies were made of temperature, moisture content of the soil, and evaporation. The opinion of this investigator is that "—— the sap density may be used as an index of site in correlating the great complex of environmental factors with the physiological responses of the plant." The osmotic value of the sap of a species is not constant. It may be influenced by any of the environmental conditions affecting transpiration, absorption, and food manufacture. The osmotic value of the sap of plants was found to be affected more by fluctuations in the moisture conditions of the habitat than by fluctuations in temperature or light.

III.

METHODS.

1. *Collection and Preparation of Leaf Samples.*

The leaf samples were all collected between the hours of one and three in the afternoon, with the exception of those in Series III, which were collected between eleven and twelve in the morning. The leaf samples were placed, on collection, in thick walled test tubes, one and one-quarter inches in diameter, and eight inches long. The capacity of such a tube is about fifty grams of leaves. Two tubes, or approximately one hundred grams of leaves, were collected for each species. Except when composed of very large leaves, as, for example those of the water lily, such a sample consists of several hundred leaves and this number should be sufficient to insure representative results. Most samples of tree leaves were collected from one individual. From herbs, shrubs, and a few of the smaller species of trees it was impossible to secure an adequate sample from one plant. Whenever this was the case, care was taken to collect the leaf material from individuals growing in the same habitat, and, whenever possible, from closely adjacent plants.

Certain almost obvious precautions were taken in the selection of the leaf samples. Only the blade of the leaf, or if the leaf were compound, only the leaflet blades were collected. When the mid-vein was extremely prominent, as in the leaves of burdock (*Arctium minus*), dock (*Rumex patientia*), and water lily (*Castalia odorata*), it was removed; otherwise the entire leaf blade was used. Only apparently sound and healthy leaves, with a uniform green color, were chosen. Collections were made only when the external leaf surfaces were free from moisture. Samples of evergreen leaves were selected only from leaves produced during the current season's growth.

The leaf samples, collected as described, were used as material for all the determinations except that of the total moisture content of the leaves. The filled test tubes were stoppered tightly with rubber stoppers immediately after the collection of the sample and plunged at once into a freezing mixture of ice and salt at a temperature of about -20°C . The tubes were arranged in the freezing bath so that the stoppers were emerged, thus avoiding possible contamination by the ice-salt mixture. Double-walled, galvanized iron buckets, in-

sulated with cotton batting, were found serviceable as containers for the freezing mixture. The tubes were left in the ice-salt mixture from fifteen to twenty hours, in practice usually overnight. If necessary the freezing mixture was renewed.

The effect of freezing the leaf tissue is to increase the yield of sap when expressed under pressure. The sap sample is also more representative when this method is used. Dixon and Atkins (8), while working on means of extracting sap for osmotic pressure measurements, developed this method. These investigators froze the samples in liquid air. Gortner and Harris (11), also primarily concerned with osmotic pressure measurements, substituted the ice-salt bath as a more universally available mode of freezing. The method used in this investigation is essentially that developed by them. Previous workers (André, 2; Marie and Gatin, 39) had shown that successive portions of saps expressed under pressure from unfrozen tissues showed progressively increasing concentrations of solutes as measured by the depression of the freezing point. The following explanation of such results was given by Dixon and Atkins. The initial pressure forces out practically pure water through the differentially permeable cell membranes, which are freely permeable to water, but difficultly permeable to most of the solutes present in the cell sap. With increasing pressure some of the cells burst, contributing their entire complement of sap, as well as their protoplasmic contents to the portion of the sap which has already been expressed. The sap released by the bursting of the cells will contain a higher proportion of solutes than that which is forced out through the protoplasmic membranes. Increase in the pressure will cause the bursting of additional cells, therefore each successive sample will contain more solutes, and will consequently have a higher osmotic pressure. If, however, according to these workers, the tissue first be frozen, the membranes become much more freely permeable; solutes as well as water are expressed, and a more representative, as well as a larger sample is obtained. Furthermore, successive portions of sap expressed from the frozen tissues used by these investigators did not show the increasing concentrations of solutes which occurs when unfrozen tissues are used. Gortner, Lawrence and Harris (12) have shown that successive portions of sap expressed from unfrozen tissues may show decreasing concentrations of solutes, or all of the fractions may show approximately the same concentration of solutes. Newton,

Brown and Martin (46) have shown that there are slight variations in the freezing point depression (hence in the osmotic value) of successive portions of sap expressed from frozen wheat leaves. This variation is much less when the sap is expressed from frozen samples of the leaves than when it is expressed from unfrozen samples, and these investigators point out the fact that the difference in the behavior of these two samples is merely one of degree. These extensions of the results of Dixon and Atkins do not invalidate the freezing method as yielding the most representative results when the osmotic value of the expressed sap is to be measured.

There can be little doubt that the increase in permeability of the cells after the freezing treatment is due to the actual destruction of the cytoplasmic membranes and consequent death of the cells. Deciduous leaves and the leaves of evergreens in the summer condition uniformly show a greater yield of sap from frozen than from unfrozen tissues, showing that some or all of the cells in the leaves have been affected by the freezing treatment.

Knudson and Ginsberg (33) reported that the expressed tissue fluids from the leaves of *Iresine Herbstii* Hook. showed about the same value for osmotic pressure when they were prefrozen in the ice-salt mixture as when the preliminary treatment consisted in freezing them in liquid air. It would be dangerous to attempt to generalize this result to other species, however, until more data are available.

Another advantage of the prefreezing treatment is that there is little likelihood of any change taking place in the sample after it is once frozen. When samples must be collected at considerable distances from the laboratory, as was the case in this investigation, it is the only method which may be used with any assurance that considerable physical and chemical changes have not taken place in them before they can be used in experimental work.

Tubes containing frozen leaf samples were thawed by exposing to room temperature for about fifteen minutes. All samples were weighed to determine the exact amount of leaf material used in each determination. The weighing was carried out in the tubes in which the sample was collected. After weighing the tubes were kept in ice water for the short interval of time which elapsed before the sap was expressed.

2. *Expression of the Leaf Tissue Fluids.*

Knudson and Ginsberg (33) have demonstrated experimentally that the osmotic value of plant juices expressed from frozen leaf tissues varies with the pressure used in extraction. The concentration of solutes in a plant sap is dependent upon the pressure used in extracting it, and the physical and chemical properties of that sap will vary accordingly. It is important that the extractions of plant saps be made under known pressures. This standardization will make possible a duplication of a determination at any time or place that measured pressures are available. Newton, Brown, and Martin (46) have also emphasized the importance of standardizing the extraction procedure, particularly with respect to the pressure used. A press similar in design to that originated by Knudson and Ginsberg was first used. This consists of a cylinder and tightly fitting piston with a delivery pipe at the base. For the dimensions and details of the construction of this piece of apparatus, the original paper should be consulted.

The method of using this press will be briefly described. A fifteen inch square of linen cloth was folded twice and placed in the bottom of the cylinder. The sample of leaves was transferred from the tubes in which it was collected and frozen, and placed on the cloth in the bottom of the press cylinder. The cloth was drawn up around the sample and the piston inserted. Pressure was applied to the top of the piston by means of a materials testing machine* and gradually brought up to five thousand pounds to the square inch. It should be noted that the pressure was merely brought up to five thousand pounds and not maintained at that figure after it once had been attained. After the maximum has been attained there is a slow diminution in the pressure to which the leaf sample is subjected, due to the gradual exudation of sap through the delivery pipe. A uniform practice was followed of allowing the press to drain for five minutes after the maximum pressure had been attained. In some of the earlier determinations muslin cloth was used instead of linen, but the tensile strength of the muslin was not always sufficient to withstand the pressures used, consequently it frequently ruptured with an accompany-

* The writer is indebted to Professor Horace Judd, of the Department of Mechanical Engineering of the Ohio State University, for permission to use this machine.

ing extrusion of leaf material through the delivery pipe. This style of press proved heavy and cumbersome for general work. Furthermore, the piston frequently became stuck in the cylinder, and could only be removed by mechanical means, an awkward and tedious procedure. The atmospheric pressure on a piston with this top area (12.56 square inches) is about one hundred and ninety pounds and this is sufficient to prevent its removal by hand whenever the leaf sample becomes tightly enough wadded into the bottom of the press cylinder to prevent the ingress of air through the delivery pipe. For these reasons a smaller and improved press was designed for these investigations. The essential design is similar to that of the press previously employed. The piston and cylinder were turned from steel and ground to fit within .0015 inch. The piston is five and one-half inches high and three inches in diameter. The cylinder is six inches high and has an outside diameter of four inches. Its inside diameter is three inches, and it is bored out to a depth of four and one-half inches.

A groove cut around the inside wall of the cylinder one inch from the top was designed to act as a liquid seal and prevent the upward movement of sap past that point. A groove was also cut around the base of the cylinder, adjacent to the vertical wall. This was designed to collect the sap and feed it to the two delivery pipes on opposite sides of the cylinder. These tubes were made of brass and threaded into place so that they might easily be removed for cleaning. An important addition to the press is a metal disk one-quarter inch thick, of a diameter slightly smaller than the inside diameter of the cylinder. On the lower side of this disk are eight equally spaced radiating grooves, one-eighth inch wide and one-eighth inch deep. Six one-sixteenth inch holes, spaced at equal intervals, are drilled through the metal disk into each groove. The removal of both the piston and the metal disk from the cylinder is facilitated by means of handles which screw into place. A press of these dimensions will readily accommodate a hundred gram leaf sample.

The employment of the metal disk described above makes it possible to practically dispense with the use of cloth for wrapping the samples. Two or three disks of linen cloth, cut to a slightly larger diameter than the cylinder, and placed on top of the metal disk are all that is required. In fact, when leaves containing considerable amounts of ligneous tissue are used, the linen disks can be dispensed with. The leaf sample is placed

directly on top of the cloth disks. The elimination of cloth for wrapping the sample is one of the advantages of the re-designed press. It is also convenient in that it is small, light and easily handled, and that all parts may be readily cleaned. If used with reasonable care, the piston never sticks in the cylinder. This type of press is well adapted for the collection of samples of expressed sap at successively increasing pressures and for determining pressure dehydration curves for plant tissues. It may also be used to determine the pressure necessary to express a given quantity of sap. Presses of this design may be built of any convenient size. They are superior to any type within the writer's experience for general work in the expression of plant tissue fluids.

The expressed plant juices were still cool as they came from the press. They were collected in porcelain evaporating dishes, poured immediately into graduated test tubes, and kept in ice water until used for further determinations. Of course it is impossible to maintain the integrity of an expressed leaf fluid for even a second after it is forced from the tissues. Oxidations occur as soon as the fluid comes in contact with the air, sometimes accompanied by a conspicuous darkening of the sap. Internal changes in such a complex system of physical and chemical equilibria as a plant sap are bound to occur. This is particularly true since many of the compounds brought together in the sap were separate in the leaf tissues. Chemical and physical changes in the saps were minimized as far as possible by keeping them in stoppered tubes in ice water. Furthermore, determinations of the properties of the saps were made as soon as practicable after their extraction. The time intervening between the expression of the sap and the completion of determinations upon that sap was never more than four hours, and was usually much less. Tests made of the osmotic value of several saps kept under these conditions showed that no appreciable change in this property, at least, occurred within this period of time.

Equal weights of leaves from different species of plants showed marked differences in the yield of sap. The range, for a hundred gram sample was from two cubic centimeters in *Tsuga canadensis* (hemlock) to sixty-seven cubic centimeters in *Bryophyllum calycinum*. The exact amount of juice expressed was measured as accurately as feasible. The delivery pipes were unscrewed and drained. When linen cloth was used for

wrapping the samples before placing them in the press, the amount of water absorbed by the cloth was determined by drying in an oven at 103°C. No appreciable error is incurred by considering the weight of the water evaporated as equal to the amount of sap which had been absorbed by the cloth. Even when the redesigned press was employed and the only cloth used consisted of several linen disks, this correction was made. The amount of sap absorbed by three of these disks, the number usually employed, seldom exceeds one cubic centimeter, however, and for many practical purposes can be disregarded.

The fact that equal sized samples of different species of leaves yielded varying amounts of sap when subjected to the same treatment and pressure made it important to carry out determinations of the total water content of each leaf tissue. With these data available it is possible to determine how much of this variation in the amount of water which can be expressed is due to variations in the water content of the leaf tissues, and how much of it is due to the resistance of those tissues to dehydration under pressure. The total water content of the leaves was determined by drying approximately twenty-five gram samples of leaf tissue to constant weight in an oven at 103°C.

3. *Determination of the Osmotic Value of the Expressed Leaf Saps.*

The determination of the depression of the freezing point of the expressed leaf juices was made by the classical method originated by Beckmann (5). Gortner and Harris (11) have discussed the application of this method to plant saps and have suggested several modifications in apparatus and technique which greatly facilitate the determination. Several of these suggestions were followed in the present work; insulation of the freezing bath, use of a metal air jacket, and employment of auxiliary freezing baths.

A double-walled, galvanized iron can, insulated with cotton batting, makes a convenient freezing bath. This bucket is seven inches high, three inches in internal diameter, and has a space between the walls of one and one-half inches. A metal cover is also provided through which is inserted a stopper holding a metal air jacket. A brass tube, one and one-eighth inches in internal diameter, and about six inches long, stoppered

at the bottom, makes a satisfactory air jacket. This air jacket is plugged with a rubber stopper through which is inserted a hard glass freezing tube. Culture tubes, 18 x 150 mm. are well adapted for this purpose. A Haidenhain thermometer was used with this freezing point apparatus. It is less cumbersome than the more familiar Beckmann type and the smaller size of the bulb permits the use of smaller freezing tubes and smaller samples of sap. As little as four cubic centimeters of sap will suffice with this arrangement. Moreover, the Haidenhain thermometer is less susceptible to change in the zero point than the standard Beckmann type*. This slow change has probably been correctly explained by Atkins (3) as due to the distillation of mercury from the curved surface of the hanging drop at the top of the reservoir of the Beckmann thermometer to the flat surface at the lower end. It is well known that the vapor pressure of a convex surface is greater than that of a flat surface. In the Haidenhain model there is only one mercury surface so that such a distillation with a consequent change in the zero point of the thermometer is impossible. There are slight changes in the zero point of this type, however, due probably to minute fluctuations in the volume of the thermometer bulb, probably due, in part, at least, to aging of the glass. For this reason the freezing point of distilled water was checked every few days throughout the season's determinations. The variation in three months was found to be less than .01 degree. The freezing tube is also provided with a rubber stopper and stirring rod. A stirring rod may also be provided for the freezing bath if desired, but the insulation makes this unnecessary.

In practice, several auxiliary baths were used, depending upon the number of determinations to be made. These baths were water-ice-salt mixtures, cooled to -1° or -2°C . Wide-mouthed thermos bottles (internal diameter two inches) make very satisfactory containers for these auxiliary baths. About five cubic centimeters of sap, centrifuged to remove suspended debris, were poured into a freezing tube, a thermometer and a stirring rod inserted through the stopper, and the tube placed in one of the pre-cooling baths. Several samples may be cooling at one time. After the mercury had fallen into the capillary, the freezing tube and attached thermometer were transferred to the freezing bath. This may be at a temperature of -10 to -15

* Improved models of the Beckmann thermometer are now on the market of such construction that change in the zero point is at a minimum.

degrees. The fact that the mercury is already low in the capillary and that the freezing tube is surrounded by a jacket of air permits the use of such a low temperature. The sample was slowly stirred until undercooling and subsequent freezing had taken place. A thermometer reading must be taken both for the point of maximum undercooling (convergence temperature) and for the freezing point. Rapid agitation of the sap sample with the stirring rod was sometimes resorted to to induce crystallization. Usually, however, this was unnecessary. With this technique, after a little practice, from five to six determinations may be made in one hour. Between determinations the metal air jacket was kept plugged with a rubber stopper in order to keep the air at a low temperature. It is also advisable to provide the air jacket with a thermometer so that a check may be kept on its exact temperature.

Observed freezing point depressions were corrected for undercooling by the formula of Harris and Gortner $D = D' - .0125u D'$ (14). Harris (31) has recently expanded it into a table which greatly facilitates corrections for undercooling. The corrected freezing point depression readings were converted into equivalent osmotic values from Harris and Gortner's tables (14, 15). The direct relation between the freezing point and the osmotic pressure is expressed by the equation $O.P = 12.06D - 0.021D^2$, (Lewis 35). The table cited is based on this formula.

4. *Determination of the Percent of Solid Matter and the Colloidal Content of the Leaf Saps.*

Gortner and Hoffman (13) were the first to point out that the colloidal content of a plant sap may be an important physical property. A method for determining the relative amount of hydrophilic colloids present in plant saps has been introduced by Newton and Gortner (44). This method expresses the colloidal content in terms of "bound water". The method will be briefly reviewed, but for details the original paper should be consulted.

The solid matter content of the sap is first obtained by the refractometer method of Gortner and Hoffman (13). An Abbe-Hilgard refractometer was used*. The percentage of water in the sap was obtained from published tables of the United States Bureau of Standards (56), and the total solids calculated

* Lent to the writer by courtesy of Dr. Alpheus W. Smith, of the Department of Physics of the Ohio State University.

from these data. This method seems to be at least as accurate as the alternative method of desiccation *in vacuo*, and is more economical of time and apparatus.

The freezing point depression of the sap is determined. A fresh sample of the sap containing exactly ten grams of water is then weighed out. To this is added 3.422 grams of sucrose, just sufficient to make a weight molecular solution. The sucrose crystals are first ground fine in a mortar to insure rapid solution. The freezing point depression of a weight molecular solution of sucrose is 2.085 degrees. This value is in excess of the usual molecular freezing point depression (1.86) because of the hydration of the sucrose molecules and consequent reduction in the amount of available solvent. Six molecules of water are bound to each molecule of sucrose (Scatchard, 50). Hence one mol of sucrose binds six mols or 108 grams of water. The net result is one mol of hydrated sucrose dissolved in 892 grams of water. Since this is more concentrated than a molecular solution the freezing point depression is greater than the molecular lowering. After the addition and solution of the the sucrose, the freezing point depression of the sap sample is redetermined. This value is usually found to be greater than the original freezing point depression plus 2.085. This excess depression is considered to be due to the fact that part of the water is "bound" by hydrophilic colloids present in the sap and is thus unavailable as a solvent. That is, the sucrose solution is more concentrated than a weight molecular solution because the 8.92 grams of water not bound by the sucrose are not all free to act as a solvent, and consequently the freezing point depression of the solution is greater.

The percent of bound water is calculated as follows:

$$\text{Bound water} = \frac{D' - (D + 2.085)}{D' - D} \times 89.2.$$

D is the freezing point depression of the expressed juice, D' is the freezing point depression after the addition of the sucrose, 2.085 is the molecular freezing point depression for sucrose, and 89.2 is the percentage of free water in a weight molecular solution of sucrose.

This method is adapted to numerous modifications in technique. In general, it consists in producing a known change in the concentration of a solution for which the depression of the freezing point is known. The resulting change in the depression

of the freezing point is measured and compared with the change calculated for the known change in concentration. If the depression of the freezing point is greater than the theoretical expectation, it measures the amount of water unavailable for solution, i. e. the bound water.

If the bound water be absorbed, as Newton and Gortner's work seems to indicate, this method should give an approximate measure of the surface area of the colloids available for absorption. It is not a measure of the mass of material present in the sap in the hydrophilic colloid state, as the same mass may have different surface areas depending upon the degree of dispersion and shape of the particles.

The possible sources of error in this method have been discussed by its originators. The validity of the method as a measure of the hydrophilic colloid content of a sap rests upon the assumption that there are no other substances present in the sap which bind appreciable amounts of water. The only non-colloidal substance which is likely to be present in plant saps in such amounts as to bind appreciable amounts of water is sucrose. An initial concentration of sucrose in the sap equal to a five percent solution, for example, would bind about 1.6% of the water present. This possible source of error is not emphasized by the originators of this method, but in the interpretation of the results of an investigation covering a variety of plant saps it should be borne in mind.

IV.

THE RANGE OF PHYSICAL PROPERTIES IN THE LEAVES OF NATIVE OHIO PLANTS.

This investigation was conducted during the summer of 1925. Leaf samples were taken from about fifty species of plants, practically all of which are native to central Ohio. Determinations were made of the total water content of the leaves, the amount of sap expressed from the leaves under a standard treatment and pressure, and of the osmotic value, percent of solid matter, and colloidal content of the expressed leaf juices. A standard method of freezing all samples in an ice-salt mixture overnight, and expressing the sap under 5000 pounds of pressure was followed, as described in the preceding section. Unless this pre-freezing and high-pressure extraction method were used, the leaves of many of the ligneous species

investigated failed to yield sufficient volumes of sap to permit these determinations. This method unquestionably yields representative results for measurements of the osmotic value and solid matter content of the expressed tissue fluids. The pre-freezing treatment presumably has a precipitating effect on the cell proteins, and this source of error may affect the determination of the colloidal content of the sap.

A summary of the data resulting from these determinations is presented in Table 1. Series I represents plants from a mixed mesophytic ravine forest and an adjacent oak hickory forest near Columbus. Series II consists of plants from near Sugar Grove, Ohio. Leaves of *Rhododendron maximum* (rhododendron) and *Tsuga canadensis* (hemlock) were collected from the north facing slope of a deep, moist ravine. This habitat is abundantly supplied with soil water. All the other plants in this series grew on the top of a high, well-drained ridge. This was the driest habitat studied. This ridge is forested with an open forest of mixed *Pinus rigida* (pitch pine) and *Pinus virginiana* (scrub pine), which is evidently the pioneer tree association in a secondary succession. The shrubs and younger trees are all deciduous with the exception of the broad leaved evergreen, *Kalmia latifolia* (mountain laurel). Series III was taken from the banks of the Big Walnut Creek near Columbus. Series IV represents bog plants and hydrophytes from Buckeye Lake and the associated bog. *Alnus rugosa* (smooth alder), *Pyrus arbutifolia* (chokeberry), *Vaccinium macrocarpon* (cranberry), *Gaylussacia baccata* (black huckleberry), and *Osmunda cinnamomea* (cinnamon fern) were taken from the bog proper. This bog is surrounded by the artificially formed Buckeye Lake and the remaining plants in the series, with the exception of *Castalia odorata* (water lily), grow on the margin between the bog and lake. They are typically pond or swamp margin plants. *Castalia* was taken as an example of a submerged hydrophyte with floating leaves. Series V consists of some common herbaceous weeds. Series VI was taken from the garden and Series VII from the greenhouse of the Department of Botany.

The date of collection is given for each sample. The columns of data, in order, represent the percentage of water in the leaves, the number of cubic centimeters of sap expressed per hundred grams of sample under a pressure of 5000 pounds per square inch, the percent of the total water present which is expressed

as sap under this pressure, the osmotic value of the expressed sap in atmospheres, the percentage of total solids in the expressed sap, and the percentage of bound water in the expressed sap. Blanks appear in the table only where the volume of sap obtained proved inadequate for the missing determinations, or where accidents occurred to the samples.

Discussion will be restricted largely to the range of these physical properties in the species, and over the variety of habitats studied. The water content of the leaves ranges from 51.9% in *Fagus grandifolia* (beech) to 92.7% in *Bryophyllum calycinum*. The averages for the plants studied are trees 60.1%, shrubs 63.7%, and herbs (exclusive of the two species taken from the greenhouse) 76.4%.

The number of cubic centimeters of sap which could be expressed from one hundred grams of leaf tissue under a pressure of 5000 pounds to the square inch varied from two in *Tsuga canadensis* (hemlock) to sixty-eight in *Bryophyllum calycinum*.

That the volume of water expressed is based, in part, at least, on other factors than the water content of the leaves is shown by the fact that the percent of the total water which can be expressed as sap shows a remarkable variation among the different species studied. The range is from 3.4% in *Tsuga* to 88.0% in *Helianthus*. The volume of water which can be expressed from a sample of leaves by pressure may have an important physiological significance. This volume will depend upon the water content of the leaf tissues, the mechanical resistance offered by the tissues to pressure, and the affinity of the tissues for water. In studies of seasonal variations in the amounts of sap which can be expressed from mature leaves, variations in the first two of these factors are frequently so small as to be negligible. Newton (45) found that it was impossible to express appreciable amounts of sap from pre-frozen samples of winter hardy wheat during the winter months. During the summer, however, relatively large amounts could be expressed. The writer has found a similar seasonal variation in the amounts of sap which can be expressed from the leaves of native Ohio evergreens. The data on which this statement is based will be published in a subsequent paper. It seems clear, as Newton has pointed out, that this phenomenon must be due to seasonal shifts in the amount and physical condition of the intracellular colloids. It is his belief that larger amounts of water are bound by these colloids in the winter than in the

summer, due probably to the fact that most of the cell colloids are in the gel condition during the winter months. This is probably an important factor in the frost resistance of species with evergreen leaves. Young leaves, in which vacuolation of the cells is not yet complete, should offer a greater resistance to the expression of sap under pressure than mature leaves, since larger proportions of the water in the cells of young leaves are bound by molecular forces. This may account for the fact that the young leaves of some species are more resistant to freezing than mature leaves. No critical experimentation has yet been carried out upon the relative resistance offered by young and mature leaves to the expression of sap under pressure.

The data on osmotic value corroborate the results of earlier investigators in regard to the relation between this property and growth form. Trees in general have higher osmotic values for the expressed leaf sap than herbs, and shrubs occupy an intermediate position. The three groups are by no means mutually exclusive, and for some herbs the osmotic value of the expressed sap was found to be almost as high as the most extreme found in trees. The average for herbs, exclusive of those taken from the greenhouse, is 13.6 atmospheres, for shrubs 16.0 atmospheres, and for trees 17.2 atmospheres. The range for ligneous species is from 11.79 atmospheres in *Rhododendron maximum* (rhododendron) to 21.30 atmospheres in *Populus deltoides* (cottonwood). There is no marked correlation of the osmotic value of the expressed leaf sap with habitat, and Korstian's conception of such a relation is not substantiated. Of course it should be recognized that the extremes of habitat represented in the Ohio flora do not approach the extremes found in Utah, where Korstian's work was done. On the other hand there is clearly a marked difference in terms of environmental factors of a habitat on the margin of a stream, represented by Series III, and one at the summit of a well drained and usually dry ridge, represented by most of the plants in Series II. Yet the two habitats are scarcely distinguishable on the basis of the osmotic values of the expressed leaf saps. The determinations for the trees of the dry ridge average slightly more than one atmosphere higher than the determinations for the trees along the stream margin. Unless differences in the habitat factors are more extreme than the differences between the habitats in central Ohio the osmotic value of the expressed leaf sap is apparently not a safe criterion of site.

The percent of total solids in the expressed saps shows a range of from 1.3% in *Zebrina pendula* (wandering jew) to 20.15% in *Rhus copallina* (dwarf sumac). The average for the plants studied in this investigation are 8.0% for herbs, 12.8% for shrubs, and 13.0% for trees. It appears that trees and shrubs, in general have a higher percent of solid matter in the expressed leaf sap than herbaceous plants.

The percentage of bound water in the expressed leaf tissue fluids ranges from none in *Castalia odorata* (water lily), *Osmunda cinnamomea* (cinnamon fern), and *Zea mais* (corn) to 23.4% in *Pinus rigida* (pitch pine). The average for the plants studied in this investigation are 12.6% for trees, 8.7% for shrubs, and 5.7% for herbs. The average for trees is distinctly higher than that for shrubs, and the average for shrubs is, in turn, markedly higher than that for herbs. The range of variability of this physical property of the expressed saps within each of these three groups is greater than for the other two physical properties of the sap studied. Apparently there is no correlation between the percent of bound water in the sap and the habitat.

It is clear, that over the range of habitats studied, the physical properties of the leaves are more closely correlated with growth form than with the factors of the environment. Herbaceous plants, in general, have a higher leaf water content than ligneous plants. The sap expressed from the leaves of herbaceous plants usually shows a lower osmotic value, a lower percentage of solid matter, and a smaller percent of bound water than the sap expressed from the leaves of ligneous plants. Shrubs usually occupy a position intermediate between trees and shrubs in regard to these measurements.

TABLE I.
SUMMARY OF THE PHYSICAL PROPERTIES OF LEAVES AND LEAF SAPS.

Date	Plant	Water Content of Leaves, Percent	Sap Yield cc. per 100 Grams	Percent of Total Water Expressed	Osmotic Value of Sap in Atmos- pheres	Total Solids Percent	"Bound Water" Percent
SERIES I.							
Aug. 3	<i>Quercus alba</i>	56.1	24	42.7	20.39	14.3	0.9
Aug. 6	<i>Quercus imbricaria</i>	55.7	6	10.7	16.26	10.7	11.4
Aug. 12	<i>Celastrus scandens</i>	76.4	59	77.2	12.52	7.5	11.6
Aug. 12	<i>Cercis canadensis</i>	71.1	40	56.2	13.06	5.7	6.3
Aug. 12	<i>Benzoin aestivale</i>	77.7	54	69.4	12.3	11.2	7.4
Aug. 12	<i>Quercus velutina</i>	56.9	7	12.3	18.17	15.5	10.8
Aug. 30	<i>Fagus grandifolia</i>	51.9	18	34.6	17.27	16.8	5.1
Sept. 18	<i>Acer rubrum</i>	55.8	27	48.3	20.42	8.8	8.6
Sept. 14	<i>Acer saccharum</i> var. <i>nigrum</i>	58.2	28	48.1	19.74	11.1	5.8
Sept. 14	<i>Sassafras variifolium</i>	61.4	23	37.4	18.14	12.9	18.4
Sept. 14	<i>Carya glabra</i>	57.3	18	31.4	15.06	11.5	7.5
SERIES II.							
Aug. 5	<i>Rhododendron maximum</i>	62.0	44	71.0	18.14	12.0	6.4
Sept. 15	<i>Tsuga canadensis</i>	57.9	2	3.4	15.72	20.1	8.7
Aug. 8	<i>Kalmia latifolia</i>	55.7	21	37.7	18.40	14.8	23.4
Aug. 8	<i>Acer rubrum</i>	58.4	25	42.8	19.02	14.9	6.1
Aug. 8	<i>Oxydendrum arboreum</i>	75.2	53	70.4	17.34	11.9	8.7
Aug. 23	<i>Gaultheria procumbens</i>	62.0	32	61.5	18.21	15.04	23.4
Aug. 23	<i>Smilax glauca</i>	82.7	44	53.2	15.22	11.1	6.1
Aug. 23	<i>Rhus copallina</i>	63.0	45	71.4	18.14	11.1	5.1
Aug. 23	<i>Cornus florida</i>	64.8	45	69.4	18.14	11.1	5.1
Sept. 15	<i>Pinus rigida</i>	66.2	45	67.9	18.14	11.1	5.1
Sept. 18	<i>Acer rubrum</i>	56.5	30	53.0	18.14	11.1	5.1
Sept. 24	<i>Sassafras variifolium</i>	70.9	25	31.7	18.14	11.1	5.1
Sept. 24	<i>Castanea dentata</i>	59.9	16	26.7	18.14	11.1	5.1

SERIES III.									
25	Aug. 20	Acer saccharinum.....	58.3	27	46.3	14.54	11.9	5.0	
26	Aug. 20	Salix alba.....	63.3	36	56.8	14.22	11.4	10.2	
27	Aug. 20	Platanus occidentalis.....	65.0	45	66.1	12.08	8.2	5.2	
28	Sept. 14	Populus deltoides.....		43		21.30	16.6	10.3	
SERIES IV.									
29	Aug. 17	Alnus rugosa.....	55.1	29	52.6	17.51	13.6	6.9	
30	Aug. 17	Pyrus arbutifolia.....	59.2	6	10.1				
31	Aug. 26	Vaccinium macrocarpon.....	62.4	40	76.3	19.22	17.5	12.8	
32	Aug. 26	Caylussacia baccata.....	55.7	33	59.2	19.08	17.4	9.8	
33	Aug. 26	Osmunda cinnamomea.....	74.9	55	73.4	14.88	8.4	0.0	
34	Aug. 26	Hibiscus Moscheutos.....	68.7	48	69.8	12.98	9.8	10.6	
35	Sept. 20	Decodon verticillatus.....	73.1	40	51.2	14.18	7.8	9.8	
36	Sept. 20	Sagittaria latifolia.....	81.5	30	36.8	13.24	7.7	7.3	
37	Sept. 20	Typha latifolia.....	77.9	24	30.8				
38	Sept. 20	Polygonum amphibian.....	71.9	54	75.1	11.80	7.1	5.3	
39	Aug. 26	Castalia odorata.....	75.9	64	74.5	14.74	8.4	0.0	
SERIES V.									
40	July 16	Taraxacum officinale.....	87.8			13.58	5.2	5.1	
41	July 19	Abutilon Theophrasti.....	68.2			13.04	9.4	3.6	
42	July 23	Saponaria officinalis.....	78.8			13.35	7.6	11.8	
43	July 23	Arctium minus.....	87.0			10.84		11.2	
44	July 24	Rumex Patientia.....	91.6			6.68	3.4	6.9	
45	Sept. 14	Verbascum Thapsus.....	71.3	51	71.0	13.42	12.5	1.8	
46	Sept. 18	Poa pratensis.....	77.6	64	82.4	13.60	5.1	3.8	
SERIES VI.									
47	Aug. 30	Helianthus annuus.....	62.5	55	88.0	18.82	8.1	7.8	
48	Aug. 30	Zea mais.....	68.2	48	70.3	19.31	11.1	0.0	
SERIES VII.									
49	July 20	Zebrina pendula.....	89.2			4.81	1.3	5.0	
50	Nov. 9	Bryophyllum calycinum.....	92.7	68	72.8	5.79	4.5	2.3	

V.

SUMMARY.

1. A study has been made of the range of certain physical properties of the leaves and of the expressed leaf saps from plants native to central Ohio. Determinations have been made of the water content of the leaves, the yield of sap from the leaves under standard treatment and pressure; and of the osmotic value, solid matter content, and colloidal content of the expressed leaf saps.

2. A specially constructed press of the cylinder and piston type is described which involves certain new principals in design. This press has given satisfactory results for the expression of leaf tissue fluids from a variety of plants.

3. The numerical range of the physical properties of leaves and expressed leaf saps has been adequately summarized in Table I. The physical properties of the leaves of any species may be regarded as taxonomic characters, variable, of course, within certain limits depending upon the environment of the plants, and the maturity of the leaves.

4. No general correlation between the physical properties of leaves and habitat could be discovered. The osmotic value of the expressed leaf sap cannot be taken as a safe criterion of site over the range of habitats found in central Ohio.

5. The physical properties of the leaves of herbaceous plants as a class are quite different from those of ligneous plants as a class. The leaves of herbs usually have a higher water content than the leaves of ligneous plants. Sap expressed from the leaves of herbs usually has a lower osmotic value, lower solid matter content, and a lower colloid content (measured as bound water) than sap expressed from the leaves of trees and shrubs. Shrubs, in general, show values for these physical properties intermediate between those for trees and herbs.

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VI.

LITERATURE CITED.

1. ABBE, C. Influence of cold on plants, a résumé. *Exp. Sta. Record* Vol. 6. p. 777. 1895.
2. ANDRE, G. Sur la composition des liquides qui circulent dans la végétale. *Compt. Rend. Acad. Sci (Paris)* 142: 106-108. 1906.
3. ATKINS, W. G. R. Osmotic pressures of the blood and eggs of birds. *Sci. Pro. Roy. Dub. Soc. n. s.* 12: 123-30. 1910.
4. BAAKE, A. L. Studies on the transpiring power of plants as indicated by the method of standardized hygrometric paper. *Jour. Ecol.* 2: 145-173. 1914.
5. BECKMANN, E. Ueber die Methode der Molecularwichtsbestimmung durch Gefrierpunktniedrigung. *Ztschr. Phys. Chem.* 2: 638-45. 1888.
6. BLACKMAN, F. F. Vegetation and frost. *New Phytol.* 8: 354-62. 1909.
7. CHANDLER, W. H. The killing of plant tissue by low temperature. *Mo. Agr. Exp. Sta. Res. Bul.* 8: 143-309. 1913.
8. DIXON, H. H., and ATKINS, W. G. R. Osmotic pressures in plants. I. Methods of extracting sap from plant organs. *Sci. Pro. Roy. Dub. Soc. n. s.* 13: 422-33. 1913.
9. ———, and ATKINS, W. G. R. Osmotic pressures in plants. II. Cryoscopic and conductivity measurements on some vegetable saps. *Sci. Pro. Roy. Dub. Soc. n. s.* 13: 436-40. 1913.
10. GORKE, H. Ueber Chemische Vorgaenge beim Erfrieren der Pflanzen. *Landw. Vers. Stat.* 65: 149-60. 1906.
11. GORTNER, R. A., and HARRIS, J. A. Notes on the technique of the determination of the depression of the freezing point of vegetable saps. *Plant World* 17: 49-53. 1914.
12. ———, LAWRENCE, J. V., and HARRIS, J. A. The extraction of sap from plant tissues by pressure. *Biochem. Bul.* 5: 139-42. 1916.
13. ———, and HOFFMAN, W. Determination of the moisture content of expressed plant tissue fluids. *Bot. Gaz.* 74: 442-46. 1922.
14. HARRIS, J. A., and GORTNER, R. A. Notes on the calculation of the osmotic pressure of expressed vegetable saps from the depression of the freezing point. *Amer. Jour. Bot.* 1: 75-78. 1914.
15. ——— An extension to 5.99° of tables to determine the osmotic pressure of expressed vegetable saps from the depression of the freezing point. *Amer. Jour. Bot.* 2: 418-19. 1915.
16. ———, LAWRENCE, J. V., and GORTNER, R. A. On the osmotic pressure of the juices of desert plants. *Science* 41: 656-58. 1915.
17. ———, LAWRENCE, J. V., and GORTNER, R. A. The cryoscopic constants of expressed vegetable saps as related to local environmental conditions in the Arizona deserts. *Physiol. Res.* 2: 1-49. 1916.
18. ———, and LAWRENCE, J. V. On the osmotic pressure of the tissue fluids of Jamaican Lorantheae parasitic on various hosts. *Amer. Jour. Bot.* 3: 438-55. 1916.
19. ——— Physical chemistry in the service of phytogeography. *Science* 46: 25-30. 1917.
20. ———, and LAWRENCE, J. V. Cryoscopic determinations on the tissue fluids of plants of Jamaican coastal deserts. *Bot. Gaz.* 64: 285-305. 1917.
21. ———, and LAWRENCE, J. V. The osmotic concentration of the tissue fluids of Jamaican montane forest vegetation. *Amer. Jour. Bot.* 4: 268-98. 1917.
22. ———, GORTNER, R. A., and LAWRENCE, J. V. The relationship between the osmotic concentration of leaf sap and the height of leaf insertion in trees. *Bul. Torrey Bot. Club* 44: 267-86. 1917.
23. ——— On the osmotic concentration of the tissue fluids of desert Lorantheae. *Mem. Torrey Bot. Club* 17: 307-15. 1917.
24. ———, and LAWRENCE, J. V. The osmotic concentration of the sap of the leaves of mangrove trees. *Biol. Bul.* 32: 202-11. 1917.
25. ——— On the osmotic concentration of the tissue fluids of Phanerogamic epiphytes. *Amer. Jour. Bot.* 5: 490-506. 1918.
26. ———, GORTNER, R. A., and LAWRENCE, J. V. On the relationship between the freezing point lowering and the specific electrical conductivity of plant tissue fluids. *Science* 52: 494-95. 1920.

27. ———, GORTNER, R. A., and LAWRENCE, J. V. On the differentiation of the leaf tissue fluids of ligneous and herbaceous plants with respect to osmotic concentration and electrical conductivity. *Jour. Gen. Physiol.* 3: 343-45. 1921.
28. ———, GORTNER, R. A., and LAWRENCE, J. V. The osmotic concentration and electrical conductivity of the tissue fluids of ligneous and herbaceous plants. *Jour. Phys. Chem.* 25: 122-46. 1921.
29. ———, and others. Maximum values of osmotic concentration in plant tissue fluids. *Proc. Soc. Exp. Biol. and Med.* 18: 106-109. 1921.
30. ———, and others. The osmotic concentration, specific electrical conductivity, and chlorid content of the tissue fluids of the indicator plants of Tooele Valley, Utah. *Jour. Agr. Res.* 27: 893-924. 1924.
31. ———. A table to facilitate correction for undercooling in cryoscopic work. *Amer. Jour. Bot.* 12: 499-501. 1925.
32. HARVEY, R. B. Hardening process in plants and developments from frost injury. *Jour. Agr. Res.* 15: 83-112. 1918.
33. KNUDSON, L., and GINSBERG, S. Suggestions with respect to the measurement of osmotic pressure. *Amer. Jour. Bot.* 8: 164-70. 1921.
34. KORSTIAN, C. F. Density of cell sap in relation to environmental conditions in the Wasatch Mountains of Utah. *Jour. Agr. Res.* 28: 845-907. 1924.
35. LEWIS, G. N. The osmotic pressure of concentrated solutions and the laws of the perfect solution. *Jour. Amer. Chem. Soc.* 30: 668-83. 1908.
36. LIDFORSS, B. Die Wintergruene Flora. *Lunds. Univ. Arsskr.* 2. 76 p. (Cited by Blackman (6), Chandler (7), Harvey (32), Maximow (40) and Newton (45).)
37. LIVINGSTON, B. E. The resistance offered by leaves to transpirational water loss. *Plant World* 16: 1-35. 1913.
38. ———, and SHREVE, F. The distribution of vegetation in the United States as related to climatic conditions. *Carnegie Inst. of Wash. Pub.* 284. 1921.
39. MARIE, C. H., and GATIN, C. L. Determinations cryoscopiques effectuées sur des sucs vegetaux. *Comparaison d'espèces de montagne avec les memes espèces de plane.* *Ass. franc. avanc. sci. (Dyon)* 40: 492-94. 1912.
40. MAXIMOW, N. A. Chemische Schutzmittel der Pflanzen gegen Erfrieren. *Ber. Deutsch. Bot. Gesell.* 30: 58-65, 293-305, 504-16. 1912.
41. ———. The physiological basis of drought-resistance of plants. (English abstract). Leningrad 1926.
42. MOLISCH, H. Das Erfrieren von Pflanzen bei Temperaturen ueber dem Eispunkt. *Sitzb. K. Akad. Wiss. (Vienna)* 105: p. 82, 95. 1896. (Cited by Harvey (32)).
43. MÜLLER-THURGAU, H. Ueber das Gefrieren und Erfrieren der Pflanzen. *Landw. Jahr.* 9: 133-89. 1880.
44. NEWTON, R., and GORTNER, R. A. A method for estimating hydrophilic colloid content of expressed plant tissue fluids. *Bot. Gaz.* 74: 442-46. 1922.
45. ———. The nature and practical measurement of frost resistance in winter wheat. *Univ. Alberta Res. Bul. I.* 1924.
46. ———, BROWN, W. R., and MARTIN, W. M. The extraction of plant tissue fluids and their utility in physiological studies. *Plant Physiol.* 1: 57-65. 1926.
47. POOL, R. J. Xerophytism and comparative leaf anatomy in relation to transpiring power. *Bot. Gaz.* 76: 221-40. 1923.
48. ROSA, T. J., JR. The nature of hardening in vegetable plants. *Proc. Amer. Soc. Hort. Sci.* 16: 190-97. 1920.
49. SAYRE, J. D. The relation of hairy leaf coverings to the resistance of leaves to transpiration. *Ohio Jour. Sci.* 20: 55-86. 1920.
50. SCATCHARD, G. The hydration of sucrose in water solution as calculated from vapor pressure measurements. *Jour. Amer. Chem. Soc.* 43: 2406-18. 1921.
51. SCHAFFNIT, E. Ueber den Einfluss niederer Temperaturen auf die Pflanzliche Zelle. *Mitt. Kaiser Wilhelm Inst. Landw. Bromberg.* 3: 93-115. 1910.
52. TRANSEAU, E. N. Forest centers of eastern North America. *Amer. Nat.* 39: 875-89. 1905.
53. WARMING, E. *Lehrbuch der Oekologischen Pflanzengeographie.* 442 pp. Berlin 1902.
54. WIEGAND, K. M. Ice in plant tissue. *Plant World* 9: 25-39. 1906.
55. ———. The passage of water from the cell during freezing. *Plant World* 9: 107-118. 1906.
56. ———. Polarimetry. Circular 44, U. S. Bureau of Standards. Washington 1918.

THE ROCK SECTION AT THE O'SHAUGHNESSY DAM.

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For the purpose of securing additional water supply, the city of Columbus constructed during 1922 to 1925, a new dam on the Scioto river in the southwest corner of Delaware County about 15 miles northwest of Columbus. The excavations incident to the building of this dam exposed a section of rocks 90 feet thick which was studied from time to time by the writer.

The bed rock exposed along this portion of the Scioto valley is the Columbus limestone of middle Devonian age and the section that was exposed at the dam included the entire thickness of the Columbus and a few feet of the Delaware limestone above and of the Monroe dolomite below. The rocks exposed were correlated by zones with the standard section of the Columbus limestone for central Ohio as worked out by Dr. Clinton R. Stauffer and published in Bulletin 10 of the Geological Survey of Ohio.* The section as seen in the excavations during the building of the dam is given below:

	Thickness Feet
<i>Delaware Limestone—</i>	
Bluish limestone in layers of 3 to 6 inches.....	3+
<i>Columbus Limestone, 87 feet—</i>	
Zone H. Bluish gray, fossiliferous limestone in layers of 1 to 2 feet. The base is at a very smooth plane.....	7
Zone G. Bluish gray, fossiliferous limestone in layers of 3 to 5 feet...	19
Zone F. Bluish gray, very fossiliferous limestone with <i>Spirifer gregarius</i> (<i>Spirifer gregarius</i> zone).....	4
Zone E. Bluish gray limestone that weathers buff. In layers of 12 to 18 inches. Upper half fossiliferous.....	14
Zone D. Grayish brown limestone with bands of chert nodules and some chert layers (Chert zone). Contains a number of gastropods..	12½
Zone C. Missing.	
Zone B. Brown dolomitic limestone with some banding and in thick ledges of 3 to 5 feet. The basal 8 feet is more compact and contains some sand grains.....	30
Zone A. Arenaceous limestone matrix with pebbles of Monroe dolomite and chert. (Conglomerate zone).....	½
<i>Monroe Dolomite—</i>	
Ashen gray to drab, laminated argillaceous dolomite in beds of 2 to 8 inches. In part brecciated, with minute fragments.....	2+

* 1909; Geol. Surv. Ohio, Bull. 10, pp. 32-38.

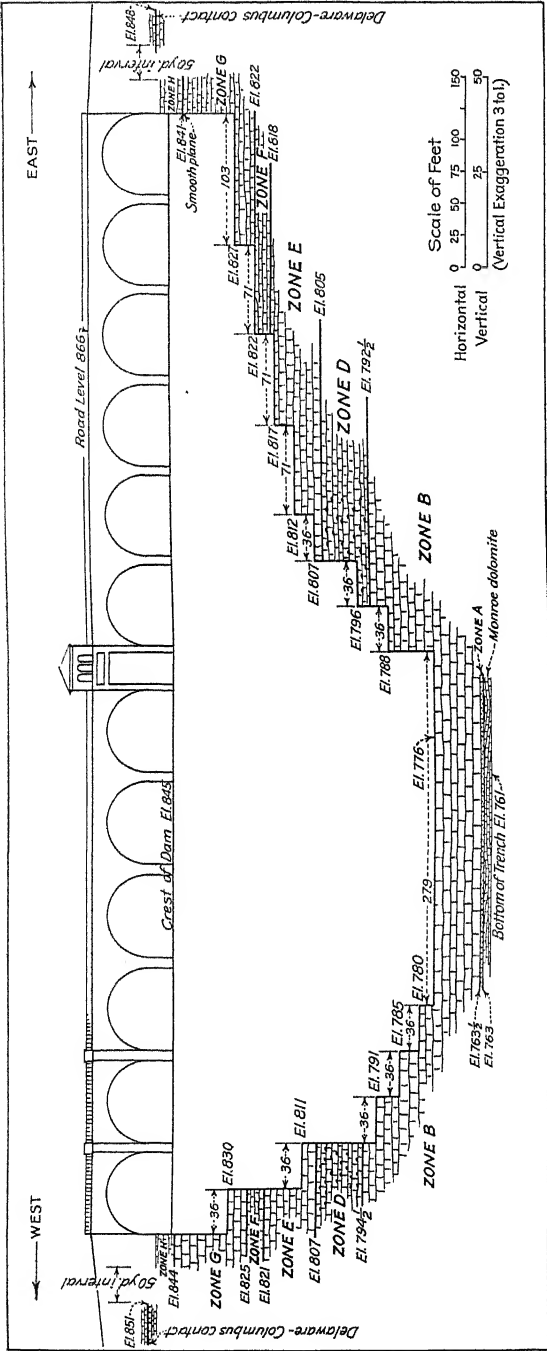


FIGURE 1.
Cross-section of the Scioto valley at the down-stream face of the O'Shaughnessy Dam, showing the location of the zones of the Columbus limestone with respect to the various rock benches.

In Figure 1 is shown a cross section of the Scioto valley at the O'Shaughnessy dam as one sees it looking up stream from the south toward the face of the dam. The section, which is drawn to scale, shows the altitude and width of the various rock benches just south of the dam and the location of the exposures of the several zones of the Columbus limestone with respect to these benches and the valley sides. The zonal contacts are 2 to 3 feet lower on the east side than on the west, due to the general eastward dip of the rocks of the region. The elevation of the bed rock in the bed of the river here was at about 775 feet above sea level and the rock formed the valley sides up to about 845 feet.

The excavation for the foundation of the dam, reached the Monroe dolomite at 13 feet beneath the rock floor of the valley at 763 feet A. T., and extended 2 feet into the Monroe. The nearest exposure of this formation is 7 miles north-northwest on Mill creek near Bellpoint. North of White Sulphur, Delaware County, the Scioto river flows on the Monroe, but the southward dip of the rocks of this region, being greater than the gradient of the river, carries this formation below the bed of the river. The rock which was exposed in the bottom of the excavation at the dam is quite characteristic of the Monroe farther north in Delaware County. No Monroe fossils were seen but this is not surprising since many much larger exposures of the Monroe do not show fossils. It belongs to the Lower Monroe, or Bass Island formation, of Silurian age.

Zone A of the Columbus limestone is represented by a layer of conglomerate about 6 inches thick. The pebbles are laminated dolomite and chert from the Monroe. The matrix contains many well-rounded sand grains and in fact the sand content of the layer is greater here than at any other known exposure of this zone in central Ohio. The conglomerate layer rests disconformably upon the Monroe and the sides of the trench showed a contact irregularity of a few inches cutting across the layers of the Monroe. The zone represents the earliest deposit of the Columbus time as the sea transgressed the eroded, pebble-strewn surface of the Monroe. The sand grains were either on the surface or washed in by the encroaching sea. Their characteristics are such as to show that they were derived from the Sylvania sandstone of northern Ohio, the horizon of which is at this Monroe-Columbus hiatus.

Zone B is present on the three lower benches on the west and on the lowest bench on the east. It is a brown, dolomitic limestone in thick ledges of 3 to 5 feet, and contains few fossils. Only the upper half is exposed now but in the excavations beneath the river bed, the entire zone with a thickness of 30 feet was shown. The basal 8 to 10 feet are more compact, bluer in color, and contain some sand grains throughout the limestone. This basal part passes into the typical brown limestone above and is considered simply a phase of the basal part of the zone, laid down while the pre-Columbus surface with its sand was not yet deeply buried.

Zone C of the standard section, characterized by an abundance of corals was not differentiated in this section although the exposure of the horizon was complete. At one place in the upper part of zone B, a chert lense yielded some small corals but it could hardly be called a coral zone.

Zone D, the chert or gastropod zone, is well represented by grayish brown limestone with bands of chert nodules and some chert layers. The greatest percent of chert and the largest number of gastropods were found at a few feet below the top. The limits of the zone are not very definite but it is most distinct on the west where it has a thickness of $12\frac{1}{2}$ feet which is greater than for any of the sections given by Stauffer. This thickness is sufficient to represent the combined thickness of zones D and C but there are no corals in the lower part of the zone.

Zone E with a thickness of 14 feet underlies on the east the three benches at elevations of 817, 812 and 807 feet and the 811 foot bench on the west. It is bluish gray limestone in thick layers and the upper half is quite fossiliferous with many specimens of the gastropods *Pleuronotus* and *Euryzonia*.

The very fossiliferous limestone forming zone F underlies the 822 foot bench on the east side of the valley. It contains the characteristic fossil *Spirifer gregarius* which on some bedding planes is quite abundant. Aside from the presence of this fossil the 4 feet of limestone forming this zone might very well be included with Zone E.

Zone G underlies the highest bench on either side and is present in the outer walls of the valley. It is in thick ledges which break up to thinner beds on weathering. The top of the zone is marked by a smooth plane and this may be found at about 4 feet below the top of the rock exposure in the east wall

just south of the dam. This zone, as well as the other thick bedded zones, E and B, is broken by vertical and inclined joints.

Zone H forms the upper few feet of the rock wall on either side of the valley but the top of the zone is not reached.

Bluish limestone interpreted as Delaware limestone was taken from the bottom of a trench beneath the present roadway about 50 yards east of the east end of the dam. The elevation of this stone is only a few feet above the top of the exposure of Columbus limestone in the east bluff at the end of the dam but the contact of the two formations was not seen here. The bluish limestone that was exposed in this trench is like the basal Delaware as found in the quarries at the town of Delaware to the north and very different from the shaly basal zone of the Delaware as found along the Scioto river 10 miles south of the dam. On the west side of the valley about 100 yards northwest of the west end of the dam, in the head of a gully, 2 or 3 feet of the Delaware limestone are exposed above a stratum containing a few fish teeth, the "bone bed," which marks the top of the Columbus limestone. The Delaware stone here is similar to that taken from the trench east of the valley. Fragments of the "bone bed" were also taken from a trench beneath the present roadway less than 50 yards from the west end of the dam, the elevation of the contact here being at about 851 feet.

The data given above shows that the Delaware limestone which underlies the upland comes to within 50 yards of either end of the dam and the width of the Columbus limestone belt along the Scioto valley is here only one-fourth of a mile instead of one and one-half miles as shown on the maps of the Columbus quadrangle.* The elevation of the Columbus-Delaware contact is at about 850 feet, about 45 feet lower than on the maps noted above. This contact was also found in the large ravine from the east about one-half mile south of the dam and in the large ravine from the east about one-half mile north of the dam and in both places its elevation agrees with that found at the dam.

No attempt was made to make a complete collection of the fossils of the various zones of the Columbus limestone exposed at the dam. Such fossils as were collected are listed below and their distribution by zones shown.

* Geol. Surv. Ohio, Bull. 14, and U. S. Geol. Surv., Folio No. 197.

	ZONES					
	B	D	E	F	G	H
ANTHOZOA—						
<i>Aulacophyllum convergens</i> Hall.			x			
<i>Cystiphyllum ohioensis</i> Nicholson.						x
<i>Cystiphyllum vesiculosum</i> Goldfuss.				x	x	
<i>Eridophyllum verniculanum</i> (Edwards and Haime).			x	x		
<i>Favosites emmonsii</i> Rominger.			x			
<i>Favosites turbinatus</i> Billings.			x	x	x	x
<i>Heliophyllum cornicula</i> Edwards and Haime.				x	x	
<i>Zaphrentis gigantea</i> Rafinesque.		x	x	x		x
<i>Zaphrentis prolifica</i> Billings.			*	x	x	x
HYDROZOA—						
<i>Stromatopora ponderosa</i> Nicholson.	x		x			
BRACHIOPODA—						
<i>Atrypa reticularis</i> (Linnaeus).	x	x	x		x	x
<i>Atrypa spinosa</i> Hall.			x	x	x	x
<i>Camarotoecchia billingsi</i> Hall.	x					
<i>Chonetes mucronatus</i> Hall.				x	x	x
<i>Meristella nasuta</i> (Conrad).		x				
<i>Productella spinulicosta</i> Hall.				x		
<i>Rhipidomella vanuxemi</i> Hall.			x			
<i>Schizophoria propinqua</i> Hall.			x		x	x
<i>Spirifer acuminatus</i> (Conrad).				x		x
<i>Spirifer duodenarius</i> (Hall).					x	
<i>Spirifer gregarius</i> Clapp.			x	x	x	
<i>Spirifer grieri</i> Hall.		x		x		
<i>Spirifer macrothyris</i> Hall.			x			
<i>Spirifer manni</i> Hall.			x			
<i>Spirifer varicosus</i> Hall.		x				
<i>Stropheodonta hemispherica</i> Hall.	x	x	x	x	x	x
<i>Stropheodonta porplana</i> (Conrad).		x			x	
<i>Strophonella ampla</i> Hall.			x			
PELECYPODA—						
<i>Conocardium cuneus</i> (Conrad).	x	x	x	x	x	
<i>Modiomorpha subalata</i> (Conrad).		*				
<i>Modiomorpha concentrica</i> (Conrad).		x	x	x		
<i>Paracyclas elliptica</i> Hall.					x	
<i>Pterinea flabellum</i> (Conrad).			x			
<i>Sanguinolites sanduskiensis</i> Meek.			x			
GASTROPODA—						
<i>Bellerophon pelops</i> Hall.	x	x	x			
<i>Callonema bellatulum</i> Hall.		x				
<i>Callonema lichas</i> (Hall).			x	x	x	
<i>Callonema humile</i> Meek.		x				
<i>Dentalium martini</i> (Whitfield).		x		x		
<i>Pleuronotus decewi</i> Billings.		*	x	x	x	
<i>Euryzone lucina</i> Hall.			x	x		
<i>Hormotoma desiderata</i> Hall.		x				
<i>Loxonema pexatum</i> Hall.		x				
<i>Palaeotrochus kerneyi</i> (Hall).			x			
CEPHALOPODA—						
<i>Orthoceras ohioensis</i> Hall.		x	x			
<i>Poterioceras eximium</i> Hall.					x	
<i>Ryticeras columbiense</i> Whitfield.			x	x		
<i>Spyroceras thoas</i> Hall.		x				
CRUSTACEA—						
<i>Coronura diurus</i> (Green).			x	x		
<i>Phacops cristata</i> Hall.			x			
<i>Proetus rowii</i> Green.			x	x		

* Collected by J. E. Schaefer.

A SECOND RECESSIVE FACTOR FOR BROWN PERICARP IN MAIZE.*

MARION T. MEYERS.†

Seed of a strain of maize with a brown pericarp was obtained from eastern Ohio in 1922. Records of the existence of such corn in the Corn Belt go back some 50 or 75 years (Klippart 1860), it usually being referred to as "prehistoric" or by some term indicating that it was unusual. Seed having a similar brown pericarp was obtained in 1925 from a different variety of corn being grown in western Ohio. The determining factor for brown pericarp in this strain proved to be identical genetically with that in the strain obtained earlier from eastern Ohio.

PREVIOUSLY REPORTED TYPES OF BROWN PERICARP.

The genetics of two other types of brown pericarp in maize have been reported previously. The first and more complete study was made of the interaction of the *A a* factor pair either with the factor *P* or with the factors r^{ch} and *Pl*, as reported by Emerson (1921) and Anderson and Emerson (1923). The pericarp is pigmented when either the factor *P*, or the factors r^{ch} and *Pl* are present. With *A* and either *P*, or r^{ch} *Pl*, the pericarp is red or cherry, whereas with the homozygous recessive allelomorph *a*, the pericarp is brown or brownish. The pericarp pigment due to the *P* factor is insoluble in water, whereas the pigment developed due to the r^{ch} *Pl* factors is soluble in water, is an anthocyanin, and is similar to the anthocyanins conditioned in other parts of the plants by a system of interacting factors of which the pairs *A a*, *R r*, and *Pl pl*, are members.

Anderson (1925) has reported a factor for brown pericarp which is dominant to red, in corn from Ecuador. Unlike the *A a* factor pair which affects all pigments except green and yellow in all plant parts, this factor affects pigments in the pericarp only, so far as known.

* The investigations reported in this paper were carried on at the Ohio State University in cooperation with the Ohio Agricultural Experiment Station and the United States Department of Agriculture.

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GENETIC RELATIONS OF THE NEW BROWN PERICARP FACTOR.

The brown pericarp corn found in Ohio has been found to be distinct genetically from those previously reported, as shown in the following data from crossing experiments. The factor pair responsible accordingly has been designated *Bp bp*.

Interaction with the P p factor pair.

Several crosses were made between material homozygous for the new brown pericarp from Ohio and ordinary clear pericarp strains. All of the F_1 ears of this cross were red. The combined results from all the F_2 populations from such crosses are given in Table 1.

TABLE I.

NUMBERS OF EARS WITH RED, BROWN, AND CLEAR PERICARP IN F_2 PROGENIES FROM THE CROSS, BROWN X CLEAR PERICARP, (*P bp x p Bp*).

	Red Pericarp	Brown Pericarp	Clear Pericarp
Observed frequencies..	199	67	88
Calculated frequencies on basis of 9:3:4 ratio.	199.12 ± 6.30	66.38 ± 4.95	88.50 ± 5.50
Deviation.....	.12	.62	.50

This clearly is a modified dihybrid ratio without linkage. The effect of the homozygous recessive factor for brown pericarp *bp bp* is to modify the pigment whose presence is determined by the *P* factor, from red to brown. Combining the red and brown classes in Table 1, there were 266 pigmented to 88 clear pericarp ears, obviously a 3 : 1 ratio. No pigment develops in the presence of homozygous recessive *p*, regardless of the condition of the *Bp bp* factor pair, hence the 3 : 1 ratio between the pigmented and non-pigmented ears.

The *P p* factors are members of an extensive series of multiple allelomorphs controlling the distribution and intensity of a water insoluble pigment in the pericarp and cob, (Emerson 1917, Hayes 1917, Anderson 1924 and Eyster 1925). One of this series determines variegation in pigmentation. A variegated brown ear was obtained from a selfed plant grown from an

open-pollinated brown seed. The plants grown from the seed of this ear produced mostly brown variegated ears and a few self-brown ears. A selfed plant from a related open-pollinated brown seed produced a red ear. The F_2 progeny from this ear consisted of 32 self-colored red, 10 variegated-red, and 9 self-colored brown ears, and 1 variegated-brown ear. Evidently the action of the $Bp\ bp$ factor pair is the same with at least one additional member of this extensive $P\ p$ series, modifying only the color and not the distribution of the pigment.

Relation to the $A\ a$ factor pair.

The ears of this new brown type were indistinguishable phenotypically from the brown ears resulting from the interaction of homozygous recessive a with the P or $r^{ch}\ Pl$ as noted

TABLE II.

NUMBERS OF EARS WITH RED, BROWN, AND CLEAR PERICARP, PRODUCED IN F_2 PROGENIES FROM CROSSES BETWEEN HOMOZYGOUS BROWN PERICARP AND RECESSIVE $a\ a$ PLANTS ($P\ A\ bp \times p\ a\ Bp$).

	Red Pericarp	Brown Pericarp	Clear Pericarp
Observed frequency...	365	286	230
Calculated frequency on basis of 27:21:16 ratio.....	371.67 \pm 9.89	289.08 \pm 9.40	220.25 \pm 8.67
Deviation.....	6.67	3.08	9.75

above. The $A\ a$ factor pair, however, influences pigments in other parts of the plant than the pericarp. When the production of brown is the result of segregation of the $A\ a$ factor pair, seeds with red or blue aleurone, and plants that are purple, dilute purple, sun red or dilute sun red always produce ears with either red or clear pericarp, but never ears with brown pericarp. A cross between two plants homozygous for recessive a would result in seeds with colorless aleurone and in either brown or green plants in the F_1 generation. Plants of the new brown pericarp type were crossed repeatedly with a -tester and brown plants grown from seed obtained from Dr. R. A. Emerson of Cornell University. In every case the F_1 endosperm had colored aleurone or the F_1 plants were purple and the pericarp red,

establishing the fact that a factor other than the *A a* allelomorphs was responsible for the brown in the new material. Moreover, brown pericarp ears occurred on F_2 plants carrying anthocyanin pigment as well as on brown and on green plants. The F_2 populations from such tri-hybrid crosses produced ears with red, brown and clear pericarp, as shown in Table 2.

The 27 : 21 : 16 ratio is expected if the three factors *A*, *P*, and *Bp* are not linked, if the *A a* and the *Bp bp* factor pairs are complementary in their interaction with the *P* factor, and if ears of the constitution *P a bp* are brown. The fit between the observed and the calculated frequencies for this ratio is very good, the highest value for $\frac{\text{Dev.}}{\text{P.E.}}$ being only 1.12.

The plants homozygous for both *a* and *bp* in the F_2 populations from this cross constitute a new combination. The recessive condition of either factor alone is sufficient to condition brown pigment in the presence of dominant *P*. If different steps in the physiology of the development of the pigment were disrupted by the two factors it is conceivable that the whole process might fail to come to visible completion or might give an end result different from either red or brown in the double recessive. If the ears from *P a bp* plants had clear pericarps the expected ratio in Table 2 would be 27 red; 18 brown; 19 clear, with a calculated frequency of 371.67 \pm 9.89 red; 247.78 \pm 9.00 brown; 261.54 \pm 9.15 clear. This gives a poorer fit than before, the deviations of the calculated from the observed frequencies being increased from 0.33 times to 4.25 times the P. E. in the brown class, and from 1.12 times to 3.45 times the P. E. in the clear class, the two classes affected by this change. Apparently the effect of the combination of the two factors in the homozygous recessive condition is not different from the effect of either alone.

Linkage with the Wx wx factor pair.

Eight linkage groups have been recognized up to the present time in corn. The factor pair for waxy endosperm *Wx wx* is in Group I. Crosses were made between plants homozygous for brown pericarp and *wx wx* plants. The F_1 plants from this cross were backcrossed to *bp bp* plants. The plants segregating for the waxy factor in the resulting population were determined by testing the pollen of each plant with chloral-hydrate iodine.

The polysaccharide reserve of pollen grains bearing the *wx* factor stains red with iodine while the polysaccharide reserve of pollen grains bearing the *Wx* factor stains blue, (Demerec 1924, and Brink and MacGillivray 1924). The ears then were classified at harvest to obtain data on the segregation for the factor for brown pericarp. The distribution obtained in the classification of these backcross populations is given in Table 3.

TABLE III.

NUMBERS OF EARS WITH RED AND WITH BROWN PERICARP ON *Wx wx* AND *Wx* PLANTS

$$\text{FROM THE BACKCROSS } \frac{P \ Wx \ bp}{p \ wx \ Bp} \times P \ Wx \ bp.$$

	EARS WITH	
	Red Pericarp	Brown Pericarp
Plants segregating for <i>Wx wx</i>	49	9
Plants homozygous for <i>Wx</i>	9	56

The 18 cross-overs in a total of 123 plants indicate a crossing-over percentage of 14.63 ± 3.19 per cent.

SUMMARY.

The genetic relationships of a second recessive factor for brown pericarp in maize are reported.

The new factor, designated *bp*, is recessive to its normal allelomorph *Bp* for red, and is expressed only in interaction with the dominant *P* factor for pericarp color.

The factor *bp* is distinct from the *A a* factor pair and, although complementary with the *A a* factor pair in its behavior in interaction with large *P* factor, there is no interaction between *Bp bp* and *A a*.

The *Bp bp* factor pair is linked with the factor pair for waxy, *Wx wx*, with 14.63 ± 3.19 per cent crossing over, as determined from a back-cross population of 123 plants.

LITERATURE CITED.

- ANDERSON, E. G. 1924. Pericarp studies in maize II. The allelomorphism of a series of factors for pericarp colors. *Genetics* 9: 442-453.
- . 1925. A dominant brown pericarp color in maize. *Mich. Acad. of Sci., Arts and Letters* 5: 73-75.
- ANDERSON, E. G. and EMERSON, R. A. 1923. Pericarp studies in maize I. The inheritance of pericarp colors. *Genetics* 8: 466-476.
- BRINK, R. A., and MACGILLAVRAY, J. H. 1924. Segregation for waxy character in maize pollen and differential development of the male gametophyte. *Amer. Jour. Bot.* 11: 465-469.
- DEMEREK, M. 1924. A case of pollen dimorphism in maize. *Amer. Jour. of Bot.* 11: 461-464.
- EMERSON, R. A. 1917. Genetic studies of variegated pericarp in maize. *Genetics* 2: 1-34.
- . 1921. The genetic relations of plant colors in maize. *Cornell Univ. Agr. Expt. Sta. Memoir* 39: 1-156.
- EYSTER, W. H. 1925. Mosaic pericarp in maize. *Genetics* 10: 179-196.
- HAYES, H. K. 1917. Inheritance of a mosaic pericarp pattern color of maize. *Genetics* 2: 261-281.
- KLIPPART, J. H. 1860. *The Wheat Plant*. p. 672. Moore, Wiltach, Keys and Co., Cincinnati.

THE PRIMARY PLANT ASSOCIATIONS OF OHIO

THEIR DISTRIBUTION AND THEIR SIGNIFICANCE AS HABITAT INDICES.*†

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INTRODUCTION.

The idea of natural plant associations as indices of habitat differences is a very old one. Pioneers everywhere have used it. There is now no adequate record of these primeval plant associations, and they have been so obscured by the effects of civilization that if we wish to use them as natural indices to habitats, we must first reconstruct them from present remnants and the secondary associations that follow clearing, grazing, and other destructive processes of man.

The reconstruction of the vegetation of the past from present day conditions is often a difficult task, and it is frequently neglected in field surveys. As evidence one may cite the relatively large numbers of papers intended as descriptions of natural plant associations in various parts of the country in which the authors fail to recognize secondary associations and actually describe them as original vegetation. The distinction between primary and secondary associations is one of the first problems that should be met and solved by anyone wishing either to describe the vegetation of a region, or to discover the relations of natural vegetation to soils, climatic factors, or other natural phenomena.

The map before you is the result of an attempt by Dr. E. N. Transeau and myself to determine the distribution of the natural vegetation of Ohio as it occurred about a century and a half ago, *i. e.*, before it had been disturbed except by Indian occupancy. The data obtained in the field surveys and the conclusions reached are being checked wherever possible by data available in the earlier reports on the vegetation of the state found in county histories, reports of travelers, early

* Paper read before the general session of the Ohio Academy of Science, April, 1927.

† Papers from the Department of Botany, The Ohio State University, No. 189.

geological surveys, and surveyors' records. Sears* has recently published a map of the "Ohio Virgin Forest" based upon data obtained from these early records. Some of the plant associations recognized in our field survey are indicated on this map. Their general distribution in the state as determined by Sears from early records agrees with the general distribution we have assigned them by field studies. This map is of value, therefore, as a check on the reliability of our field methods of reconstructing the original vegetation.

Several vacation periods were spent in studying the least disturbed areas, remnants of original forests, and numerous secondary forests in various parts of Ohio and neighboring states. In this preliminary work emphasis was placed on learning to recognize the several plant associations, both primary and secondary, and also the successions that might occur among them. We then began to map the distribution of the original plant associations of the entire state. Last summer Dr. L. L. Huber, Dr. J. S. Houser, and Director Williams of the Ohio Experiment Station saw that our data had a bearing on some of the problems in which they are interested and furnished us financial aid. If this assistance continues we shall have the vegetation map ready for publication much sooner than we had anticipated.

Geological and soil maps of the state have been published and attempts have been made to correlate the natural vegetation with these maps. It is mainly of these mutual interests that I wish to speak today: to point out (1) some of the features of the natural vegetation that should be considered in future attempts to determine such correlations as exist, and (2) that the distribution of the natural plant associations of the state is itself an index of environmental conditions with potentially distinct uses and value.

THE PRIMARY PLANT ASSOCIATIONS.

Previous to the nineteenth century there were more than thirty well recognized primary plant associations in the state. Four of these associations: Beech-Maple, Elm-Ash-Maple, Oak-Hickory, and Mixed Mesophytic are of first importance on the basis of area covered. Their distribution is indicated on the

*Sears, P. B. The natural vegetation of Ohio. Ohio Jour. Sci. 25:139-149, 1926.

map.* Of secondary importance on the basis of area covered by the association are: Willow, Alder, River Birch, and Maple-Cottonwood-Sycamore Associations along some of the streams; Oak-Chestnut or Oak-Chestnut-Hickory on sandy or gravelly areas, dryer talus and hill tops, and certain stages of cliff erosion; White Pine in northeastern Ohio and Pitch Pine in southeastern Ohio as cliff associations; Post Oak-Bur Oak between Oak-Hickory and prairie and as isolated groves on the prairie; Oak-Maple as a transition between Beech-Maple and Oak-Hickory near the prairie, but usually not elsewhere; Slough Grass and Andropogon associations of the wet and dry prairies respectively; Scirpus-Typha-Phragmites marshes; Cranberry, Alder, Tamarack, Aborvitae, White Pine and Hemlock associations of bogs; Birch, Hemlock-Birch, and Beech-Maple-Hemlock-Birch associations in gorges, deep ravines, and on steep slopes. The last named association also occurred on uplands in the extreme northeastern part of the state. Since the map is on display where you may observe the distribution of these associations at your convenience, further details of distribution will be omitted at this time.

The present distribution of these associations represents the latest moves in a long series of successions. The succession of plant associations is now a well established law in biology and should be recognized in all modern field studies. As the habitat factors change, the associations change, and these changes follow orderly sequences that may be detected by appropriate methods of investigation.

The successions that should be kept in mind in studying natural vegetation in this state are of three types. First, the historical successions of a geographical order including (a) successions following the retreat of the glacier, (b) successions during the post-glacial xerothermic period, (c) successions subsequent to that period. Second, the primary successions accompanying the changes in soil and atmosphere of the present time. Third, the numerous secondary successions following clearing and other activities of man. Several associations in the state are lingering relics of the first type of succession noted above.

* Since this is mainly a report of progress and suggestions for future investigations, the map in its present stage of development is omitted from publication.

SIGNIFICANCE OF THE PRIMARY PLANT ASSOCIATIONS AS HABITAT INDICES.

The first point of importance is that the primary plant associations represent a summation of both the atmospheric and soil factors acting over a period of years.

As a point in evidence it may be noted that their general distribution in the state is not coincident with geological formations, glaciation, soil types, temperature, rainfall, or any other single environmental factor or restricted group of environmental factors. Their distribution is a resultant of all the atmospheric and soil factors acting simultaneously.

The effects of certain environmental factors are of course more prominent than those of others. But the factors showing the most prominent effects in one locality of the state, are not necessarily the most prominent in effect in another locality. For example as we approach the prairie areas of Ohio Beech-Maple disappears, first from the uplands then from the ravines. Oak-Maple becomes the usual forest for a few miles, then Oak-Hickory becomes the common forest on all the uplands. Exactly the same changes in forests occur as we go westward and approach the prairie climate of the Central States. This similarity in the changes of forests in the two cases indicates that atmospheric factors are most effective in determining the Oak-Hickory association in certain parts of the state. On the other hand, topography and soil factors becoming unfavorable for Beech-Maple are as clearly the most effective factors accounting for Oak-Hickory in certain other localities.

As another example we may choose a single soil type*, say Wooster loam, and if a rather extensive area of this soil type is traversed we can find growing upon it associations of Oak-Chestnut, Oak-Hickory, Beech-Maple, Oak-Maple, and Mixed Mesophytic. This dissimilarity of plant associations on the same soil type results mainly in some instances from differences in atmospheric factors, in other instances from changes in the soil factors most effective in plant growth but not given the most weight in classifying the soil type. Furthermore these same five associations occur on other soil types in other parts of the state. Or the same association, such as Beech-Maple, occurs on numerous soil types. This similarity of plant associations on different soil types shows that some of the soil character-

* The distribution of soil types was obtained from published maps.

istics chosen to distinguish soil types may hold a very minor position among the factors that affect plant development and distribution. Where soil types are distinguished on the basis of variations in water and oxygen content, interesting relations of soil type and vegetation do occur locally.

Another condition that should be recognized is that the relative effects of soil and atmospheric factors varies geographically. Transeau emphasized this point several years ago in his paper on "Forest Centers."* He recognized in each of the climatic plant formations of the continent a "center of distribution" in which the plants of that formation reached their best development. One of the characteristics of this center of distribution is that the differential effects of topography and other soil factors are less effective there than elsewhere in the formation, and that as one departs farther and farther from the center of distribution the relative effects of topography and soil become more noticeable.

It must also be remembered that the effect of one plant association upon another, the biotic effect, is a factor in their distribution. So far as climate and soil alone are concerned the Oak-Hickory association would occupy most of the area of the state. But when these conditions become suitable also for Beech-Maple or Mixed Mesophytic forests, Oak-Hickory is shaded out. However if clearing continues, secondary Oak-Hickory will occupy most of the area originally covered by these associations. The chief exceptions are the secondary forests of swamp forest species following the clearing of Beech-Maple on poorly drained areas.

A second point of importance is that if we may add to our knowledge of the primary associations an understanding of the secondary associations that follow the first clearing of the primary, we shall have a still better basis for the evaluation of the atmospheric and soil factors.

The secondary forests following a single clearing of the primary associations are not the same in different parts of the state. As an example, the secondary forests that may follow a single clearing of the Beech-Maple association in various parts of the state are: Beech-Maple, Maple-Beech, Oak-Maple, Oak-Hickory, Oak-Chestnut, Mixed Mesophytic, and Elm-Ash-Maple.

*Transeau, E. N. Forest Centers of eastern North America. *Am. Nat.* 39:875-889, 1905.

An interpretation of these variations in secondary forests in relation to atmospheric and soil factors in a given region can frequently not be made without a thorough knowledge of the biotic factors involved, both present and historical. A knowledge of these secondary associations following the first, second, and third clearings would have its uses, particularly in the field of forestry. Clearing is making an enormous change in the proportion of the state occupied by each of the several forest associations.

The third point of importance is that since the natural plant associations represent a summation of the atmospheric and soil factors, they ought to serve as convenient indices of biological habitats in the study of certain agricultural problems. Along with other general indices of habitats, such as geological formations, soil types, and summations of atmospheric conditions, they should serve as an additional and a distinctly different type of measure of habitat conditions. No single index or unit of measure will suffice.

Is there any evidence that the natural plant associations may be used as indices to biological habitats in the state under present agricultural conditions? I have already indicated their possible relations to forestry problems. We are of the opinion that a knowledge of the primary and secondary associations and of the successions among them, will furnish a valuable foundation upon which to predict the types of forests that may most readily be maintained in different parts of the state. But the final working out of these correlations must be delegated to the forester.

The most carefully analyzed correlation to date is that between the distribution of natural plant associations and certain insect infestations in the state. In 1924 Mr. Merlin Jones a student in entomology at this University furnished us a map of the distribution and of the degree of infestation of the Mexican bean beetle in this state. When Jones' map was superimposed upon our vegetation map there was seen to be a close correlation between the distribution of the Mixed Mexophytic forest and the areas in which the Mexican bean beetle was doing commercial damage. Field studies last summer by Dr. Transeau and Mr. N. F. Howard of the U. S. Bureau of Entomology showed this correlation to be surprisingly constant.

When the corn borer invasion became alarming, Dr. Transeau suggested that it would probably not do commercial

damage in all habitats and that the natural plant associations might furnish an index to the habitats in which it would do commercial damage. Dr. L. L. Huber had already noted in 1924 that the degree of infestation varied locally with certain habitat conditions. The Experiment Station agreed that the idea was worth investigation.

The conditions in Ontario were used as a preliminary test case. We determined the distribution of the primary plant associations in the entire corn borer area of Ontario. When our vegetation map was compared with maps of the corn borer infestation furnished by the entomologists* it was found that the corn borer had been doing commercial damage in Ontario only in those areas originally occupied by the Swamp Formation, *i.e.*, the series of successions from marsh grasses through intermediate associations of bog and swamp vegetation to the Elm-Ash-Maple swamp forest association of the Eastern Deciduous Forest. The borer had been present equally long in other habitats in Ontario but its devastation there had not been considered of commercial significance. The survey was then extended to include the corn borer area in Ohio and neighboring states. At the close of the season our vegetation maps were compared with Dr. Huber's maps of the distribution and the degree of infestation of the corn borer. The correlation discovered in Ontario was found to hold throughout the entire region investigated.† These two examples of insect devastation indicate how the natural plant associations may serve as convenient indices in predicting the habitats in which the depredation of certain insects should either be controlled or avoided.

Perhaps the behavior of some of our cultivated plants will show equally interesting correlations. But students familiar with the behavior of cultivated plants must be persuaded to help supply and evaluate the data necessary to bring out such correlations as exist. Mr. J. H. Gourley of the Ohio Experiment Station suggested in conversation that most of the com-

*Numerous entomologists contributed data and personal assistance. General acknowledgment is made to Dr. L. L. Huber and Dr. C. R. Neiswander, of the Ohio Experiment Station; to H. G. Crawford, Chief of the Division of Field Crops and Garden Insects, Canada; and to Dr. E. P. Felt, State Entomologist, New York.

† A paper on "Vegetation Types and Insect Devastation," by E. N. Transeau, is to appear in the July number of *Ecology*, and may be consulted for a more detailed account of this topic.

mercial orchards in Ohio are in that part of the State where our map shows an abundance of the mixed mesophytic forest in the valleys and of Oak-Hickory on the hilltops. Orchard trees as perennial plants are subject to the environmental factors of the habitat during the entire year just as are the natural plant associations, while many other cultivated plants are annuals and subject to the factors of the habitat only during the growing season. It is beyond the scope of this paper to attempt an enumeration of the complexities of the situation. I wish merely to call attention to two more conditions that are in keeping with the general tenor of this discussion.

First, agricultural practices modify many of the factors of the natural habitat. The general effects of these modifications can be appreciated at once if we direct our attention to the manner in which external factors frequently affect plant development and distribution. The general conclusion that may be drawn from the data of numerous field studies and experimentation on the causes of the differences in distribution of the plant associations characteristic of this region is that the external factors foremost in limiting the distribution of these associations in Ohio are the factors that bring about within the plant either desiccation, starvation, or suffocation. The first condition is usually brought about by a deficiency in external moisture, at least during the growing season; the second usually by overshadowing by other plants; and the third by excess water leading to oxygen deficiency. The effects of other factors are less prominent, except perhaps for a few individual species. For example the species of the Oak-Hickory association can not withstand the desiccation of the most arid habitats in the state, their roots suffocate during the long submergence in swamps and floodplains, and they are unable to manufacture food as rapidly as they use it in the shade of beech and maple. Any agricultural practice that modifies either of the three sets of conditions named above may bring about modifications in expected correlations.

The second point is that any attempt to correlate the behavior of cultivated plants with the natural associations should not ignore the successional history of different localities. For example, two years ago I listed the successional series that have led to the Oak-Hickory and Elm-Ash-Maple associations in northeastern Ohio. The Oak-Hickory association was found to have succeeded such xerophytic associations as Pine and Oak-

Chestnut, prairie vegetation, and even swamp forest on a peculiar hydrophyllous clay soil. As a secondary association it had succeeded Beech-Maple and Mixed Mesophytic. The Elm-Ash-Maple swamp forest association had succeeded the swamp vegetation of marshes, pioneer floodplain forests, and relic bog vegetation. As a secondary association it had succeeded tamarack and other conifers on bogs, and Beech-Maple on poorly drained areas.

These different successional series of vegetation leave different effects in the soils upon which they occur and these differences may be reflected in the behavior of cultivated plants. In such cases a uniform correlation would not occur.

It is apparent that such correlations and lack of correlations as I have cited can be determined only by having each kind of survey made by specialists in the fields concerned. Our chief interest in this survey is to discover and interpret the behavior of natural plant associations. The vegetation map is of value to us as a basis in selecting critical stations for quantitative studies of the relative effects of environmental factors throughout the season. In the last analysis understanding and practice both require an evaluation of the external factors in their relation to the physiology and development of the different species and varieties. General indices to habitats have certain values, but they will not remove the need of studies of the relative effects of the separate factors of the habitat during critical periods of the year and at different stages in the development of the plant.

NEW BOOKS.

THE CENTURY COMPANY has recently issued two attractive books on scientific subjects which we are glad to bring to the attention of our readers. One of them, *Oxidation-Reduction Reactions In Inorganic Chemistry*, by Eric R. Jette, will be of interest to chemists, and the other, *Host Parasite Relations Between Man and His Intestinal Protozoa*, by Robert Hegner, will interest both the zoologist and the public health worker. The publisher's statements regarding these volumes are given below:

Host-Parasite Relations Between Man and His Intestinal Protozoa—By ROBERT HEGNER, PH. D., Professor of Protozoology in the School of Hygiene and Public Health of the Johns Hopkins University. Price, \$3.50.

The purpose of this book is to present the more relevant data regarding the host-parasite relations of the intestinal protozoa of man in such a manner as to show the present state of our knowledge and to focus attention on the need for more systematic and intensive research in the subject. The distinguishing feature of this study is its effort to co-ordinate the zoological phases of the subject with the medical phases and both the zoological and medical phases with methods of prevention and control. The control of the parasitic species, to be effective, must be based on a knowledge of the relations between the parasite and its host. What these relations are and the little we know about them is explained in this book.

This volume is the first to appear in The Century Biological Series, of which Dr. Hegner is the general editor. It is illustrated with charts, diagrams, and half-tone plates and contains a valuable twenty-five page list of references to the literature in the subject and an index of the authors quoted or referred to in the text.

Oxidation-Reduction Reactions In Inorganic Chemistry—By ERIC R. JETTE, PH. D., Assistant Professor of Chemistry at the Washington Square College of New York University. Price, \$1.10.

This book presents a comprehensive discussion of oxidation-reduction reactions for the student who has had enough training in chemistry to understand ordinary chemical terminology, but who has not had the benefit of a course in physical chemistry. It emphasizes the qualitative, rather than the quantitative, aspects of the subject; and presents both the valence change and the ion-electron methods of balancing equations in order to enable the student to balance the equations for the greatest possible number of oxidation-reduction reactions. The book aims to develop the fundamental basis of each of these methods and, to this end, introduces the modern concepts of atomic structure, the ideas of polar and non-polar compounds, and certain elementary principles of electrochemistry. The ion-electron method is discussed in detail with numerous applications which illustrate the effect of solubility, degree of ionization, concentration of ions, complex-ion formation, etc., on oxidation-reduction reactions taking place in aqueous solutions.

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